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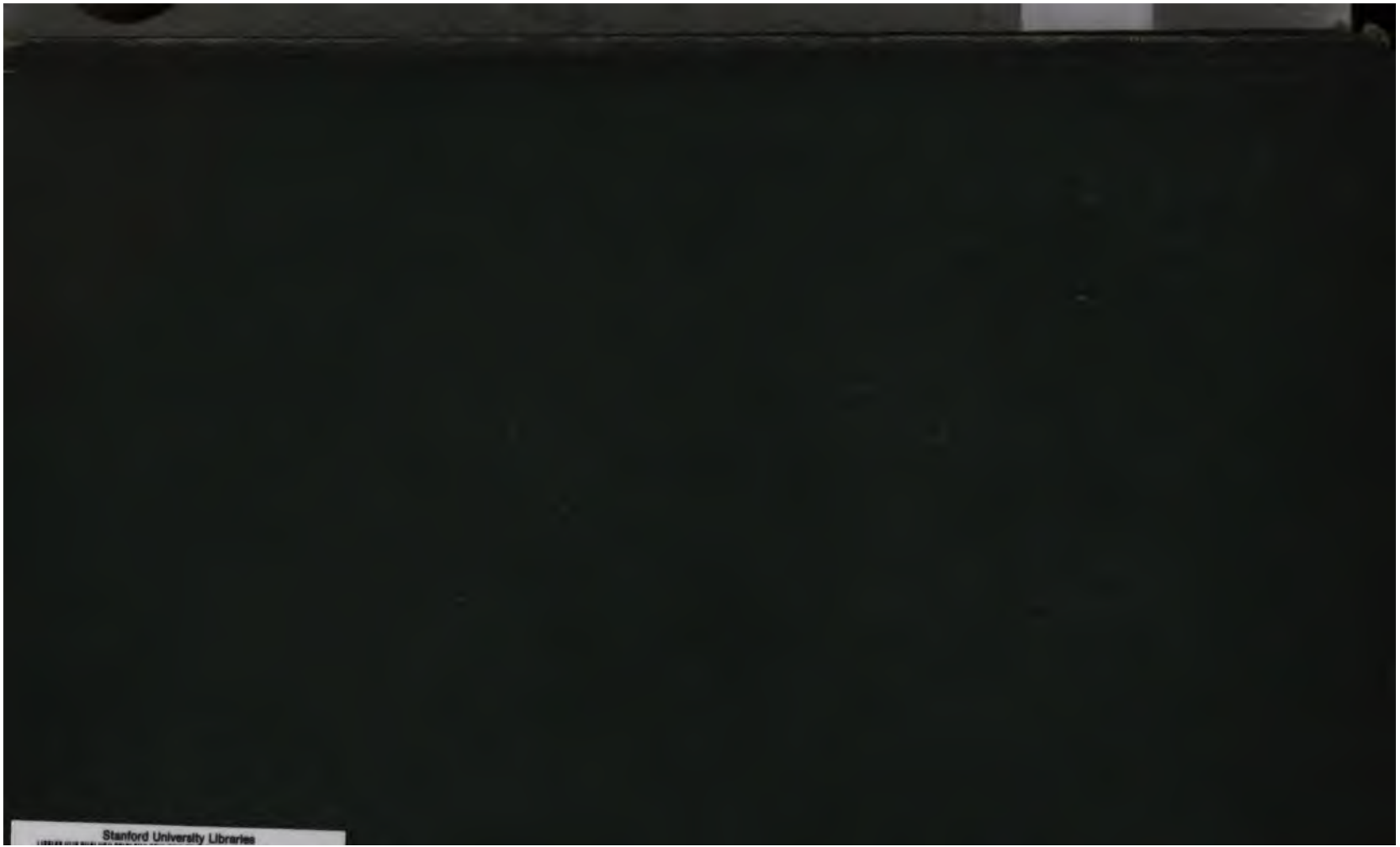
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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1893 *TO NOVEMBER* 1894.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. NOVEMBER 10, 1893. No. 1

Captain W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

William Murray Dobie, M.D., J.P., Northgate House, Chester;
Roland Pillans, Geodetic Survey, Royal Observatory, Cape of Good Hope;
Dr. Charles Lane Poor, Astronomer in the Johns Hopkins University, Baltimore, Md., U.S.A.; and
Thomas Jefferson Jackson See, Ph.D., University, Chicago, U.S.A.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

John Harrison Buckley, 70 Tower Street, Leicester (proposed by T. D. Brewin);
William Briggs, B.A., LL.B., F.C.S., Burlington House, Cambridge (proposed by Robert Bryant);
J. Evershed, Junr., Chemical Manufacturer, Kenley, Surrey (proposed by A. Cowper Ranyard);
Joshua Jukes, 43 High Street, Smethwick, near Birmingham (proposed by Arthur Mee);
Henry Alfred Lenehan, Astronomical Assistant, Government Observatory, Sydney, N.S. Wales (proposed by H. C. Russell);

Armin Otto Leuschner, A.B., Assistant Professor of Astronomy in the University of California (proposed by J. E. Keeler);

Henry MacEwen, Engineer, 5 Cathkin Terrace, Mount Florida, Glasgow (proposed by L. Becker);

The Rev. David Powell Richards, B.A., Chaplain and Naval Instructor to H.M.S. *Canada*, Bermuda;

Richard Pickering Sellors, B.A., Astronomical Observer, Government Observatory, Sydney, N.S. Wales (proposed by H. C. Russell),

Dr. Max Wolf, Professor of Astronomy in the University of Heidelberg, The Observatory, Heidelberg (proposed by A. Cowper Ranyard).

Two hundred and twelve presents were announced as having been received since the last meeting, including, amongst others: Professor O. J. Lodge, Aberration Problems; F. C. Penrose, Results of Examination of Orientation of Greek Temples; S. C. Chandler, Second Catalogue of Variable Stars; O. A. L. Pihl, On Occulting Micrometers, presented by the Authors; Barlow and Bryan, Elementary Mathematical Astronomy, second edition, presented by the Publishers; E. M. Clerke, The Planet *Venus*; E. W. Buller, Semi-Azimuths; A. Mukhopadhyay, The Geometry of Conics, presented by the Authors; J. E. Gore, An Astronomical Glossary, presented by the Publishers; M. Lœwy, Sur la Détermination des Constantes des Clichés Photographiques du Ciel; A. M. Clerke, History of Astronomy during the 19th Century; P. Henry, Mesures et Réductions des Clichés Photographiques du Catalogue de la Carte du Ciel, presented by the Authors; Leander McCormick Observatory, Observations of Southern Nebulæ; Harvard Observatory, Annals, vol. xix. pt. 2 (On the Zodiacal Light, &c.); Berlin Observatory, Zonenbeobachtungen der Sterne zwischen +20° und +25°; Kiel Observatory, Catalog der farbigen Sterne; Madras Observatory, Results of Meridian Observations, 1877–79; Cordoba Observatory, Durchmusterung, Catalogue, pt. 1, presented by the Observatories; Observations of the Transit of *Venus*, 1874, made in N.S. Wales, presented by H. C. Russell; Opere di Galileo, edizione nationale, vol. iii. (Sidereus Nuncius), presented by the Italian Government; Œuvres complètes de Laplace, tome ix., presented by the French Academy; T. G. Rylands, The Geography of Ptolemy, presented by the Author; Series of re-touched enlargements from Lick Observatory negatives of the Moon, presented by Professor Weinek; A drawing of *Saturn*, presented by B. E. Cammell; J. M. Schaeberle, Series of transparencies from negatives of the Solar Eclipse of 1893 April, presented by the Lick Observatory; A new form of planisphere, presented by A. H. Molesworth.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the Year 1892; and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables.

By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The present paper contains the observations of the Right Ascensions and North Polar Distances of the Moon, made at the Radcliffe Observatory during the year 1892. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions—

(1) That the mean times found in the usual way, from the sidereal times at mean noon given in the *Nautical Almanac*, were not altered in scale, or affected with any different systematic errors of determination, by the adoption, in 1864, of a different ratio of the Julian year of $365\frac{1}{4}$ " mean solar days " to the mean tropical year.

(2) That the " mean solar times " which accurately correspond to given " local sidereal times " before and after 1864 are necessarily different from the adoption and use of a " Julian year " and " mean solar day " which are different fractional parts of the mean tropical year, and therefore are different intervals of absolute time.

If these differences are real, and are neglected by astronomers in referring the tabular positions of the Sun, Moon, &c., to the meridians for comparison with the local sidereal times at transit, the effects of the errors made will necessarily be thrown upon the theoretical expressions.

The differences of the errors thus made in practice, according to my views, before and after 1864, are given in Table III.

The periodical errors of Hansen's Tables, after correction, shown by the observations during the year 1892, are not larger than those which will be found to exist during the years 1847 to 1863.

The mean annual errors of Hansen's Tables show small but systematic periodical changes from 1847 to 1863, but since 1864 the errors in longitude have progressively increased until they amount in 1892 to $+19''.7$. It will be seen that after the corrections, which I have indicated as necessary for a comparison of the changes of the errors of Hansen's Tables before and after 1864, have been applied, the *per saltum* change in 1864 is no longer shown. The mean annual error in longitude, 1847–63, is $-1''.85$; the mean annual error in longitude, 1864–92, is $-1''.56$; and the mean annual error in longitnde for the whole period, 1847–92, is $-1''.67$.

For facilities for an accurate comparison between Hansen's Lunar Tables and Observations I am again indebted to the places published in the *Connaissance des Temps*.

TABLE I.

Radcliffe Observations of the Moon, 1892.

R.A.'s and N.P.D.'s of the Centre of the Moon, 1892; *compared with Hansen's Tabular Places*, **Uncorrected** *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year* 1864.

Day, 1892.	Correction to be subtracted from M.T. for Change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen minus Observed. Uncorrected.	Correction due to the Change in the Unit of Mean Time.	Hansen minus Observed. Corrected.	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen minus Observed. Uncorrected.	Correction due to the Change in the Unit of Mean Time.	Hansen minus Observed. Corrected.
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Jan. 6	41·51	F.B.	I.	0 49 19·57	20·93	+1·36	−1·46	−0·10	S.	88 30 23·16	13·35	−9·81	+10·98	+1·17
7	41·52	W.	I.	1 41 51·40	52·80	+1·40	−1·48	−0·08	S.	82 3 10·94	1·25	−9·69	+10·52	+0·83
11	41·53	F.B.	I.	5 32 49·34	50·84	+1·50	−1·73	−0·23	N.	64 12 47·86	45·31	−2·55	+2·93	+0·38
13	41·54	R.	I. & II.	7 36 43·36	44·66	+1·30	−1·67	−0·37	N.	64 5 24·81	26·40	+1·59	−2·64	−1·05
15	41·55	R.	II.	9 29 56·92	58·07	+1·15	−1·47	−0·32	S.	69 53 54·79	60·20	+5·41	−6·71	−1·30
Feb. 3	41·62	F.B.	I.	1 25 6·62	7·90	+1·28	−1·50	−0·22	S.	83 47 26·14	16·19	−9·95	+10·95	+1·00
8	41·64	R.	I.	6 13 52·97	54·34	+1·37	−1·71	−0·34	N.	63 17 14·81	13·80	−1·01	+0·96	−0·05
11	41·66	F.B.	I.	9 8 54·22	55·61	+1·39	−1·50	−0·11	N.	68 25 1·66	6·50	+4·84	−6·13	−1·29
16	41·68	F.B.	II.	13 2 50·93	52·13	+1·20	−1·23	−0·03	S.	93 35 54·13	60·35	+6·22	−9·24	−3·02
Mar. 7	41·76	W.	I.	6 56 31·01	32·43	+1·42	−1·68	−0·26	N.	63 4 47·84	47·51	−0·33	−1·01	−1·34
8	41·76	R.	I.	7 55 33·50	34·95	+1·45	−1·61	−0·16	N.	64 26 35·47	38·51	+3·04	−3·50	−0·46
9	41·76	F.B.	I.	8 51 27·19	28·64	+1·45	−1·52	−0·07	N.	67 10 11·16	14·47	+3·31	−5·58	−2·27
10	41·77	F.B.	I.	9 43 46·97	48·30	+1·33	−1·42	−0·09	N.	70 58 50·23	56·72	+6·49	−7·18	−0·69
11	41·77	R.	I.	10 32 46·55	47·55	+1·00	−1·34	−0·34	N.	75 35 29·77	37·80	+8·03	−8·31	−0·28

Day, 1892.	Correction to be subtracted from M.T. for Change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Mar. 12	41 78	F.B.	I.	11 19 4·06	5·25	+ 1·19	− 1·27	− 0·08	N.	80 44 22·97	31·53	+ 8·56	− 9·03	− 0·47
18	41·80	W.	II.	15 51 17·51	18·96	+ 1·45	− 1·43	+ 0·02	S.	111 17 28·58	35·84	+ 7·26	− 6·22	+ 1·04
20	41·81	R.	II.	17 40 7·32	8·59	+ 1·27	− 1·62	− 0·35	S.	116 31 50·64	53·21	+ 2·57	− 2·31	+ 0·26
Apr. 4	41·87	W.	I.	7 37 9·89	11·23	+ 1·34	− 1·66	− 0·32	N.	63 39 36·14	37·93	+ 1·79	− 2·82	− 1·03
5	41·87	R.	I.	8 34 38·08	39·41	+ 1·33	− 1·56	− 0·23	N.	66 1 36·43	41·47	+ 5·04	− 5·06	− 0·02
6	1·88	F.B.	I.	9 28 7·35	8·51	+ 1·16	− 1·45	− 0·29	N.	69 33 48·60	54·04	+ 5·44	− 6·79	− 1·35
7	41·88	W.	I.	10 17 52·28	53·41	+ 1·13	− 1·36	− 0·23	N.	73 58 2·86	10·28	+ 7·42	− 8·04	− 0·62
8	41·88	R.	I.	11 4 35·92	36·94	+ 1·02	− 1·29	− 0·27	N.	78 58 20·90	29·30	+ 8·40	− 8·86	− 0·46
9	41·89	F.B.	I.	11 49 13·47	14·59	+ 1·12	− 1·24	− 0·12	N.	84 21 2·89	11·44	+ 8·55	− 9·33	− 0·78
11	41·90	W	I.	13 16 7·75	8·82	+ 1·07	− 1·24	− 0·17	N.&S.	95 26 52·39	61·40	+ 9·01	− 9·30	− 0·29
17	41·92	R.	II.	18 18 21·22	22·29	+ 1·07	− 1·64	− 0·57	N.	117 15 16·68	18·89	+ 2·21	− 0·67	+ 1·54
May 6	42·00	R.	I.	11 34 47·56	48·47	+ 0·91	− 1·26	− 0·35	N.	82 30 17·18	26·49	+ 9·31	− 9·26	+ 0·05
9	42·01	W.	I.	13 45 29·37	30·34	+ 0·97	− 1·26	− 0·29	N.	99 2 6·64	14·39	+ 7·75	− 9·06	− 1·31
10	42·01	R.	I.	14 30 49·07	50·12	+ 1·05	− 1·31	− 0·26	N.	104 10 16·87	24·88	+ 8·01	− 8·36	− 0·35
12	2·02	F.B.	II.	16 9 19·57	20·95	+ 1·38	− 1·48	− 0·10	S.	112 39 11·08	19·17	+ 8·09	− 5·75	+ 2·34
14	42·03	R.	II.	18 0 17·61	18·79	+ 1·18	− 1·63	− 0·45	S.	117 4 14·43	16·59	+ 2·16	− 1·46	+ 0·70
18	42·04	R.	II.	21 52 47·03	48·64	+ 1·61	− 1·56	+ 0·05	N.	108 26 56·56	48·12	− 8·44	+ 8·33	− 0·11
June 1		R.	I.	12 2 45·14	45·99	+ 0·85	− 1·25	− 0·40	N.	86 3 53·54	61·66	+ 8·12	− 9·51	− 1·39

Day, 1892.	Correction to be subtracted from M.T. for Change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
June 6	42·12	F.B.	I.	14 14 19·77	21·18	+1·41	−1·30	+0·11	N.	102 24 36·10	43·54	+7·44	−8·66	−1·22
7	42·12	R.	I.	15 1 11·72	12·74	+1·02	−1·37	−0·35	N.	107 13 58·80	66·27	+7·47	−7·70	−0·23
8	42·13	F.B.	I.	15 51 3·13	4·41	+1·28	−1·46	−0·18	N.	111 23 41·40	46·29	+4·89	−6·36	−1·47
9	42·13	W.	I.	16 44 22·11	23·38	+1·27	−1·55	−0·28	N. & S.	114 37 47·59	53·37	+5·78	−4·54	+1·24
12	42·14	R.	II.	19 39 47·51	49·05	+1·54	−1·68	−0·14	N.	116 16 11·10	10·33	−0·77	+3·01	+2·24
13	42·15	F.B.	II.	20 38 46·93	48·84	+1·91	−1·64	+0·27	N.	113 43 33·39	31·13	−2·26	+5·55	+3·29
14	42·15	W.	II.	21 35 48·52	50·35	+1·83	−1·58	+0·25	N.	109 46 49·18	44·13	−5·05	+7·75	+2·70
17	42·16	F.B.	II.	0 15 19·88	21·42	+1·54	−1·47	+0·07	N.	92 13 69·38	56·91	−12·47	+11·33	−1·14
30	42·22	W.	I.	11 44 41·85	42·89	+1·04	−1·28	−0·24	N.	83 58 32·66	40·75	+8·09	−9·58	−1·49
July 7	42·24	W.	I.	17 18 35·65	36·96	+1·31	−1·62	−0·31	S. & N.	116 4 8·78	10·73	+1·95	−3·16	−1·21
Aug. 4	42·36	W.	I.	17 51 37·63	39·01	+1·38	−1·67	−0·29	S.	117 1 49·72	48·64	−1·08	−1·69	−2·77
5	42·36	R.	I.	18 51 33·36	34·73	+1·37	−1·72	−0·35	S.	117 14 44·81	40·70	−4·11	+1·01	−3·10
12	42·39	W.	II.	1 27 18·37	20·04	+1·67	−1·52	+0·15	N.	82 33 51·12	39·20	−11·92	+11·29	−0·63
Sept. 5	42·48	W.	I.	22 21 20·77	22·28	+1·51	−1·61	−0·10	S.	105 19 40·60	30·99	−9·61	+9·98	+0·37
7	42·49	W.	II.	0 11 36·69	38·26	+1·57	−1·55	+0·02	N.	92 7 45·52	33·55	−11·97	+12·09	+0·12
8	42·50	R.	II.	1 6 3·10	4·37	+1·27	−1·56	−0·29	N.	85 2 66·84	55·74	−11·10	+11·99	+0·89
Oct. 1	42·59	W.	I.	20 55 27·01	28·38	+1·37	−1·65	−0·28	S.	112 48 38·19	32·44	−5·75	+6·65	+0·90
3	42·60	R.	I.	22 48 38·41	39·60	+1·19	−1·58	−0·39	S.	102 26 32·38	21·44	−10·94	+10·79	−0·15

Day, 1893.		Correction to be subtracted from M.T. for Change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Unoorrected Mean Times.	Hansen minus Observed. Uncorrected.	Correction due to the Change in the Unit of Mean Time.	Hansen minus Observed. Corrected.	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen minus Observed. Uncorrected.	Correction due to the Change in the Unit of Mean Time.	Hansen minus Observed. Corrected.
		s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Oct.	5	42·60	R.	I.	0 38 28·39	29·66	+1·27	−1·58	−0 31	S.	88 35 46·82	35·19	−11·63	+12·44	+0·81
	10	42·62	R.	II.	5 43 45·35	47·06	+1·71	−1·87	−0·16	N.	62 39 23·83	21 77	− 2·06	+ 2·24	+0·18
Nov.	1	42·71	R.	I.	0 9 13·70	14·72	+1·02	−1·54	−0·52	S.	92 28 11·16	1·67	− 9·49	+12·15	+2·66
	3	42·72	R.	I.	2 0 40·21	41·40	+1·19	−1·67	−0 48	S.	78 16 27·66	16·23	−11·43	+11·65	+0·22
	5	42·73	R.	II.	4 5 21·38	22·83	+1·45	−1·88	−0·43	N.	66 47 61·08	55·43	− 5·65	+ 7·33	+1·68
	29	42·82	R.	I.	0 37 4·69	5·72	+1·03	−1·51	−0·48	S.	88 43 66·29	55·95	−10·34	+11·90	+1·56
	30	42·83	R.	I.	1 30 50·17	51·28	+1·11	−1·58	−0·47	S.	81 49 12·48	2·33	−10·15	+11·76	+1·61
Dec.	3	42·84	W.	I. & II.	4 35 24·83	26·44	+1·61	−1·93	−0·32	N.	65 4 56 82	50 50	− 6·32	+ 5·88	−0·44
	12	42·88	R.	II.	13 3 6·81	7 78	+0·97	−1·26	−0·29	S.	94 44 1·55	7·00	+ 5·45	− 9·79	−4·34
	24	42·92	R.	I.	22 37 17·33	18·41	+1·08	−1·48	−0·40	S.	103 28 43·89	33·85	−10·04	+ 9·79	−0 25
	26	42·93	W.	I.	0 17 58·41	59·49	+1·08	−1·46	−0·38	S.	91 1 33·43	23·36	−10·07	+11·47	+1·40
	29	42·94	R.	I.	2 59 45·58	46·80	+1·22	−1·71	−0·49	S.	71 52 58·39	48 73	− 9·66	+ 9·52	−0·14
	30	42·95	W.	I.	4 1 42·48	43·80	+1·32	−1·84	−0·52	S.	66 58 16·66	10·13	− 6·53	+ 7·22	+0·69
Mean of Errors, without regard to sign					...		s 1·290	...	s 0·263		...	...	″ 6·696	...	″ 1·117
Mean Errors for Year					... ...		+1·290	...	−0·233						

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F.B., Mr. F. A. Bellamy.

TABLE II.

Radcliffe Observations of the Moon, 1892.

Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance, **Uncorrected** *and* **Corrected** *for the Change in the Unit of Mean Time introduced in the year* 1864.

Day, 1892.		Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude (Hansen *minus* Observed).		Errors of E.N.P.D. (Hansen *minus* Observed).	
					Uncorrected.	**Corrected.**	**Uncorrected.**	**Corrected.**
					"	"	"	"
Jan.	6	F.B.	I.	S.	+22·68	−1·84	−1·11	+0·50
	7	W.	I.	S.	+22·92	−1·41	−1·56	+0·35
	11	F.B.	I.	N.	+20·38	−3·22	−1·59	+0·23
	13	R.	I. & II.	N.	+17·60	−5·11	−1·28	−0·23
	15	R.	II.	S.	+17·16	−4·71	−0·01	+0·20
Feb.	3	F.B.	I.	S.	+21·43	−3·42	−2·16	−0·29
	8	R.	I.	N.	+18·35	−4·56	−1·46	+0·06
	11	F.B.	I.	N.	+20·04	−1·85	−1·06	−0·78
	16	F.B.	II.	S.	+19·01	−1·58	−1·16	−2·61
Mar.	7	W.	I.	N.	+18·90	−3·60	−2·16	−1·00
	8	R.	I.	N.	+19·92	−2·22	−0·82	−0·03
	9	F.B.	I.	N.	+20·27	−1·56	−2·28	−1·92
	10	F.B.	I.	N.	+20·02	−1·44	−0·13	−0·23
	11	R.	I.	N.	+16·55	−4·71	+2·08	+1·57
	12	F.B.	I.	N.	+19·61	−1·28	+0·95	+0·03
	18	W.	II.	S.	+21·35	+0·49	+2·82	+0·96
	20	R.	II.	S.	+17·15	−4·69	+1·97	+0·43
Apr.	4	W.	I.	N.	+18·09	−4·42	−1·22	−0·30
	5	R.	I.	N.	+18·99	−3·07	+0·35	+0·77
	6	F.B.	I.	N.	+17·27	−4·31	+0·02	0·00
	7	W.	I.	N.	+17·95	−3·33	+1·05	+0·62
	8	R.	I.	N.	+17·17	−3·86	+1·93	+1·11
	9	F.B.	I.	N.	+18·83	−1·96	+1·17	0·00
	11	W.	I.	N. & S.	+18·24	−2·47	+2·32	+0·69
	17	R.	II.	N.	+14·23	−7·66	+2·64	+1·31
May	6	R.	I.	N.	+16·16	−4·77	+3·18	+2·11
	9	W.	I.	N.	+16·21	−4·49	+2·11	+0·31
	10	R.	I.	N.	+17·01	−3·70	+2·78	+0·86
	12	F.B.	II.	S.	+20·31	−0·93	+4·41	+2·55
	14	R.	II.	S.	+15·79	−6·02	+2·16	+0·70
	18	R.	II.	N.	+24·56	+0·71	−0·16	+0·14

Day, 1892.	Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.	Errors of E.N.P.D (Hansen *minus* Observed). Uncorrected.	Corrected.
				″	″	″	″
June 3	R.	I.	N.	+ 14·95	− 6·06	+ 2·37	+ 1·11
6	F.B.	I.	N.	+ 21·96	+ 1·11	+ 0·17	− 1·69
7	R.	I.	N.	+ 16·13	− 4·88	+ 3·09	+ 1·18
8	F.B.	I.	N.	+ 18·50	− 2·77	+ 1·02	− 0·91
9	W.	I.	N. & S.	+ 17·95	− 3·63	+ 3·51	+ 1·72
12	R.	II.	N.	+ 20·63	− 2·24	+ 2·74	+ 1·89
13	F.B.	II.	N.	+ 26·06	+ 2·76	+ 4·50	+ 4·13
14	W.	II.	N.	+ 26·18	+ 2·48	+ 3 58	+ 3·70
17	F.B.	II.	N.	+ 26·24	+ 1·42	− 2 28	− 0·63
June 30	W.	I.	N.	+ 17·51	− 3·89	+ 1·25	+ 0·06
July 7	W.	I.	S. & N.	+ 17·78	− 4·26	+ 0·66	− 0·90
Aug. 4	W.	I.	S.	+ 18·46	− 3·92	− 1·33	− 2·72
5	R.	I.	S.	+ 18·62	− 4 38	− 2·45	− 3·51
12	W.	II.	N.	+ 27·52	+ 2·31	− 1·89	+ 0·24
Sept. 5	W.	I.	S.	+ 23·92	− 1·49	− 1 01	− 0·18
7	W.	II.	N.	+ 26·43	+ 0·23	− 1·63	+ 0·23
8	R.	II.	N.	+ 21·80	− 4·35	− 3·02	− 0·83
Oct. 1	W.	I.	S.	+ 19·88	− 3·99	− 0·28	− 0·21
3	R.	I.	S.	+ 20·34	− 5·24	− 3·49	− 2·31
5	R.	I.	S.	+ 22·15	− 4 60	− 3·23	− 1·08
10	R.	II.	N.	+ 22·85	− 2·14	− 1·43	+ 0·12
Nov. 1	R.	I.	S.	+ 17·87	− 8·24	− 2·62	− 0·66
3	R.	I.	S.	+ 20·34	− 6 69	− 4·69	− 2·23
5	R.	II.	N.	+ 20·69	− 6·14	− 1·76	+ 0 53
Nov. 29	R.	I.	S.	+ 18·32	− 7·25	− 3·44	− 1·40
30	R.	I.	S.	+ 19 03	− 7·07	− 3 38	− 1·07
Dec. 3	W.	I. & II.	N.	+ 22·60	− 4·25	− 3·13	− 1·06
12	R.	II.	S.	+ 15·49	− 5·67	− 0·52	− 2·35
Dec. 24	R.	I.	S.	+ 18·43	− 5·33	− 3·41	− 2·42
26	W.	I.	S.	+ 18·92	− 5·80	− 2·82	− 0·98
29	R.	I.	S.	+ 19·41	− 6·66	− 4·36	− 2·10
30	W.	I.	S.	+ 19·17	− 7·18	− 2·83	− 0·73
Mean of Errors, without regard to sign ...	...	...		**19″·687**	**3″·775**	**2″·032**	**1″·076**
Mean Errors for Year ...	...	...		**+ 19″·687**	**− 3″·410**	...	..

TABLE III.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 *to* 1892, *as computed from Hansen's Tables.*

Uncorrected *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year* 1864.

Year.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.	
	"	"	
1847	+ 0·51	+ 0·51	
1848	− 0·53	− 0·53	
1849	− 1·08	− 1·08	
1850	− 0·97	− 0·97	
1851	− 1·93	− 1·93	
1852	− 1·57	− 1·57	
1853	− 2·18	− 2·18	
1854	− 2·34	− 2·34	
1855	− 1·40	− 1·40	Mean Annual Error in Longitude from 1847 to 1863 = − 1″·85.
1856	− 1·51	− 1·51	
1857	− 2·41	− 2·41	
1858	− 2·61	− 2·61	
1859	− 2·49	− 2·49	
1860	− 3·62	− 3·62	
1861	− 2·95	− 2·95	
1862	− 2·83	− 2·83	
1863	− 1·61	− 1·61	
1864	+ 0·12	− 0·81	
1865	+ 1·27	− 0·22	
1866	+ 2·14	− 0·22	
1867	+ 3·48	+ 0·36	
1868	+ 4·12	+ 0·28	
1869	+ 4·28	− 0·35	
1870	+ 4·83	− 0·66	
1871	+ 6·96	+ 0·44	
1872	+ 7·31	+ 0·10	
1873	+ 8·24	+ 0·20	
1874	+ 9·29	+ 0·56	
1875	+ 9·87	+ 0·36	
1876	+ 9·80	− 0·50	
1877	+ 9·23	− 1·90	Mean Annual Error in Longitude from 1864 to 1892 (taken out with the corrected argument) = − 1″·56.
1878	+ 8·22	− 3·60	
1879	+ 9·63	− 3·12	
1880	+ 10·89	− 2·77	
1881	+ 10·51	− 4·06	
1882	+ 12·68	− 2·51	
1883	+ 14·71	− 1·50	
1884	+ 14·65	− 1·91	
1885	+ 15·20	− 1·82	
1886	+ 15·34	− 2·53	
1887	+ 15·70	− 3·25	
1888	+ 17·68	− 2·46	
1889	+ 17·37	− 3·51	
1890	+ 18·02	− 3·55	
1891	+ 19·30	− 2·90	
1892	+ 19·69	− 3·41	

1847 to 1879: Greenwich observations. 1880 to 1882: Mean of Greenwich and Radcliffe. 1883 to 1892: Radcliffe observations.

Radcliffe Observatory, Oxford:
1893 *November* 9.

Preliminary Note on the Reduction of Measures of Photographic Plates. By H. H. Turner, M.A., B.Sc.

1. The following is an attempt to simplify the processes already suggested for the reduction of measures of stellar photographs, and especially measures of the plates of the Astrographic Chart.

2. The fundamental property of a photographic plate is that it is a projection of the celestial sphere from a point (the centre of the object-glass) on a plane (the photographic plate itself). This statement must be qualified just so far as the image of the star is displaced by—

(*a*) Distortion of the objective;
(*b*) Displacements of the photographic film;
(*c*) Refraction and aberration.

3. Neglecting for the moment these disturbing causes, it follows that any great circle on the sphere projects into a straight line on the plate; and any straight line on the plate corresponds to a great circle on the sphere, and hence to a straight line on any other plate containing the same region.

4. The appropriateness of using rectilinear co-ordinates is thus suggested: for the transformation from any rectilinear co-ordinates on one plate to any rectilinear on another takes a simple form. Let (x, y), (ξ, η) be any rectilinear co-ordinates of the same point on the two plates; then the following general relations hold:

$$\xi = \frac{Ax + By + C}{Kx + Ly + M}, \qquad \eta = \frac{Dx + Ey + F}{Kx + Ly + M}.$$

It is readily seen that the denominator must be the same in the two cases, for the equation

$$\lambda\xi + \mu\eta + \nu = 0$$

represents a straight line on one plate for all values of λ, μ, ν, and hence must represent a straight line on the other. The above formulæ give the equation to this straight line, viz.

$$\lambda(Ax + By + C) + \mu(Dx + Ey + F) + \nu(Kx + Ly + M) = 0.$$

5. The above formulæ are quite general, but a more convenient form may be given to them in the case of co-ordinates measured approximately in similar directions on the two plates, as will generally be the case for the plates of the Astrographic Chart. We shall then have *approximately*

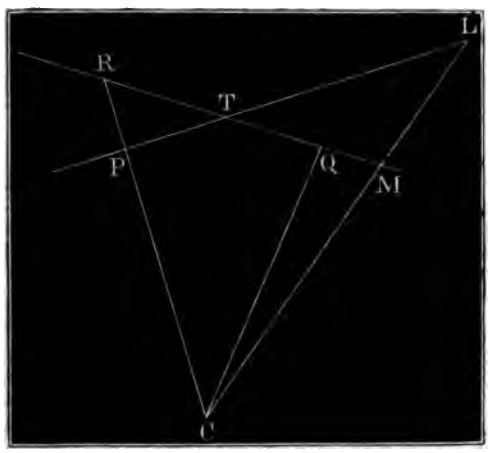
$$\xi = x + \text{const.}, \qquad \eta = y + \text{const.}.$$

and the accurate relations may be written

$$\xi = \frac{(1+a)x + by + c}{1 - kx - ly}, \qquad \eta = \frac{dx + (1+e)y + f}{1 - kx - ly},$$

where a, b, d, e, k, l are all small, and c and f are the co-ordinates of the centre of the plate (x, y) on the plate (ξ, η), which are about 1° in the case of the chart plates.

6. The meaning of the denominator may be seen most readily by taking a simple case. Let C be the centre of the sphere,



PTL, RTM two plates whose centres are P and Q; L and M the images of a star on these plates, in a plane through PCQ; PL, QM the co-ordinates x and ξ. Then if the radius CP of the sphere be taken as unity

$$\xi = \mathrm{QM} = \tan \mathrm{QCM} = \tan(\mathrm{PCL} - \mathrm{RCQ})$$

$$= \frac{\mathrm{PL} - \mathrm{RQ}}{1 + \mathrm{PL} \cdot \mathrm{RQ}}$$

$$= \frac{x - \mathrm{RQ}}{1 + x \cdot \mathrm{RQ}}$$

$$= \frac{x + c}{1 - kx},$$

where $k = c = -\mathrm{RQ}$ = the x co-ordinate of centre of plate (x, y) on plate (ξ, η). And it can be shown generally that if (x, y) (ξ, η) are measured from the centres of the two plates, our general formulæ of transformation become

$$\xi = \frac{(1+a)x + by + c}{1 - cx - fy}, \qquad \eta = \frac{dx + (1+e)y + f}{1 - cx - fy},$$

where all the quantities are in parts of the radius. If, as is usual in measuring the Astrographic Chart plates, x and y (and consequently c and f) be expressed in minutes (or seconds) of arc, instead of $k=c$, $l=f$, we shall have

$$k = \frac{c}{(3438)^2} \text{ or } \frac{c}{(206264)^2}, \text{ \&c.}$$

7. Such formulæ hold whether the co-ordinates be measured accurately in prescribed directions or not, provided they are rectilinear, but we shall often find it useful to refer to what may be called the standard co-ordinates of a plate, which are thus defined: Let A and P be the Right Ascension and N.P.D. for 1900·0 of the proposed centre of the plate; from this point draw two straight lines on the tangent plane to the celestial sphere perpendicular and parallel to the meridian for 1900·0. These lines are the axes of ξ, and η, and (ξ, η), the "standard co-ordinates" of any point whose R.A. and N.P.D. and α and p respectively, are expressible in terms of these quantities by the relations

$$\xi = \frac{\tan(\alpha - A)\sin q}{\cos(P - q)}, \qquad \eta = \tan(P - q),$$

where

$$\tan q = \tan p \cos(\alpha - A).$$

(See Note I.)

8. Let us now return to the disturbing causes mentioned in paragraph 2. Concerning distortion of the object-glass and displacements of the photographic film it is to be remarked, in the first place, that they have been shown to be small; and, secondly, that any correction for them falls outside this or any other general method of reduction. As regards

Refraction, various formulæ have been given for the differential refraction, perhaps the most elegant being those of Dr. A. A. Rambaut in *Astronomische Nachrichten*, No. 3125. He there shows that it is only necessary to retain terms of the first order in $\Delta\alpha \cos\delta$, and $\Delta\delta$, and finds the following expressions:—

$$\Delta d\alpha = \beta_0 \left(\frac{\cos\phi}{\cos\delta} \frac{\sin\nu \sin(\mu + \delta)}{\sin^2 n \sin^2(m+\delta)} d\alpha + \frac{\cot n \cos(m + 2\delta)}{\cos^2\delta \sin^2(m+\delta)} d\delta \right),$$

$$\Delta d\delta = \beta_0 \left(-\frac{\cos\phi \cos\nu}{\sin^2 n \cdot \sin^2(m+\delta)} d\alpha + \frac{1}{\sin^2(m+\delta)} d\delta \right);$$

* These formulæ are approximate only. Generally (c, f) are the co-ordinates of centre of plate (x, y) on plate (ξ, η) and $(-k, -l)$ the co-ordinates of centre of (ξ, η) on (x, y), but in the small terms involving (k, l) these are sensibly equal. (See Note IV.)

where

$$\tan m = \cot \phi \cos (\theta - \alpha) \qquad \cot \mu = \tan \phi \cos (\theta - \alpha)$$

$$\cot n = \sin m \tan (\theta - \alpha) \qquad \cot \nu = \cos \mu \tan (\theta - \alpha).$$

Elegant as these formulæ are, much simpler ones can be obtained by using rectangular co-ordinates on the plate instead of R.A. and Declination. Let X and Y be the "standard co-ordinates" (see paragraph 7) of the zenith, supposed projected on the plate. If λ be the colatitude, S the sidereal time of exposure of the plate, A and P the R.A. and N.P.D. of the centre, according to the formulæ in paragraph 7, we have

$$X = \frac{\tan (S - A) \sin q}{\cos (P - q)}, \qquad Y = \tan (P - q),$$

where

$$\tan q = \tan \lambda \cos (S - A).$$

These formulæ are very simple, and q can readily be tabulated at any given place for different values of the hour angle S − A. Then it is shown in Note II. that the corrections for refraction become

$$d\xi = \beta_0 \{(1 + X^2)\xi + XY\eta\}$$

$$d\eta = \beta_0 \{XY \cdot \xi + (1 + Y^2)\eta\},$$

where β_0 is the constant of refraction, as in Dr. Rambaut's formulæ. But the point of greatest importance is the preliminary investigation of Dr. Rambaut's paper, which shows that terms of the second order in ξ and η may be neglected, and makes the above corrections *linear* in ξ and η; for thus it follows that a straight line on the plate is still a straight line, and hence the correction for refraction is *included* in the general formulæ quoted above. No separate calculation of the refraction is therefore required. Similarly the correction for

Aberration is small, and all terms beyond those of the first order may be neglected. If (X′, Y′) be the co-ordinates of the "Earth's Way" supposed projected on the plate, the corrections for aberration are shown in Note III. to be

$$dx = \frac{\gamma_0 x}{\sqrt{1 + X'^2 + Y'^2}}$$

$$dy = \frac{\gamma_0 y}{\sqrt{1 + X'^2 + Y'^2}}.$$

These again, being linear, are included in the general formulæ, and no separate calculation of them is required.

9. The following corrections are also well known to involve

linear transformations only, and are similarly included in the general formulæ :—

That for orientation, whether of the plate in the telescope or in the measuring apparatus.

That for scale value, whether due to change in focal length of the telescope or in the measuring apparatus.

That for non-perpendicularity of the two measured co-ordinates.

10. It follows, then, that if (x, y) be the measured rectilinear co-ordinates of a star on a plate as affected by refraction, aberration, and the sources of error mentioned above; and if (ξ, η) be its "standard co-ordinates" (see paragraph 7) and κ is the number of minutes of arc in the radian: then

$$\kappa\xi = (1+\alpha)x + \beta y + \gamma, \qquad \kappa\eta = \delta x + (1+\epsilon)y + \zeta,$$

no denominator being required in these expressions if the theoretical and actual centres of the plate are nearly coincident. Now, if there are three known stars on the plate, we have six equations to determine the constants α, β, γ, δ, ϵ, ζ; or, if more stars are known, we can solve by least squares or any analogous process. It is to be noted that the equations are of the linear form specially adapted to simple solution. Knowing these constants we can convert the measured co-ordinates (x, y) of any star into standard co-ordinates (ξ, η), and *if desired* into R.A. and N.P.D. by the formulæ of paragraph 7: viz.
find q from

$$\tan (\mathrm{P} - q) = \eta,$$

then α from

$$\frac{\tan (\alpha - \mathrm{A}) \sin q}{\cos (\mathrm{P} - q)} = \xi,$$

and finally p from $\tan q = \tan p \cos (\alpha - \mathrm{A})$. But I venture to think that this final transformation will generally be unnecessary, for the "standard co-ordinates" of a star will for many purposes be far more convenient.

11. If there be not enough known stars on the plate to give a good determination of the constants α, β, γ, &c., it becomes necessary to associate with it neighbouring plates in the manner suggested by M. Loewy. The process he adopts is, however, much simplified by the present method. If we have a central plate (0), and four others (1), (2), (3), (4), whose centres are approximately at the corners of the plate (0), and if suffixes denote the fact that the co-ordinates are measured on the corresponding plate, then we have

$$x_0 = \frac{(1+a)\,x_1 + by_1 + c}{1 - \mu c x_1 - \mu f y_1}$$

$$y_0 = \frac{dx_1 + (1+e)\,y_1 + f}{1 - \mu c x_1 - \mu f y_1},$$

where

$$\mu = \frac{1}{(3438)^2}$$

and the quantities are in minutes of arc. Since the quantities $\mu c x_1 x_0$, $\mu f y_1 x_0$, &c., are very small, approximate values of c and f, such as can be found by mere inspection, will be sufficiently accurate for substitution in these terms, and we can form the quantities

$$x_0\,(1 - \mu c x_1 - \mu f y_1)$$

$$y_0\,(1 - \mu c x_1 - \mu f y_1)$$

for all the stars common to the two plates. We then have for each star two simple equations in a, b, c, d, e, f, and all these may be solved by least squares or any analogous process.

Knowing a, b, c, d, e, f, we can form (x_0, y_0) the co-ordinates of any star $(x_1 y_1)$ on the plate (1), but outside the region common to the two plates, *as though that star had been on the plate* (0) *and measured with the other stars on the same system.* We can thus virtually transfer all the known stars on the plates (1), (2), (3), (4) on to the plate (0), and increase the number of the equations for determining α, β, γ, &c., on that plate. The process is obviously capable of indefinite extension.

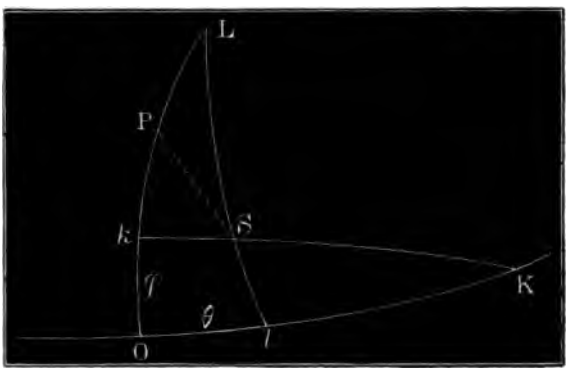
12. In view of this method of reduction by rectilinear co-ordinates, a recent decision of the Permanent Committee to publish such measures without further reduction becomes very important. It is clear that from such measures—

(1) Formulæ can quickly be deduced connecting one plate with another.

(2) The use of Right Ascensions and Declinations may be entirely deferred until we wish to deduce the final constants for any plate from known stars. Indeed, a great deal of information as to the progress of the work generally can be obtained without ever using R.A. and Declination at all, when it is once realised that measures on one plate are very simply convertible into measures on another. Rectilinear measures, instead of being very raw material, are, in fact, quite ready for use. They are readily comparable *inter se*, and with any similar measures of similar photographs to be made in the future. R.A. and Declination are a necessity of meridian and equatorial observation, but only complicate any discussion of the places of the stars.

Note I.

Let O be the centre of the plate, K and L its poles on the celestial sphere; P the North Pole of the heavens.



Let the R.A. of the centre O be A, and its N.P.D., P; and let (α, p) be the R.A. and N.P.D. of any star S on the plate.
Then

$$PS = p, \quad \angle OPS = \alpha - A, \quad OP = P;$$

$$\xi = \tan Ol = \tan \theta \text{ (say)}, \quad \eta = \tan Ok = \tan \phi.$$

In the triangle LPS

$$\cot PS \sin LP = \cos LP \cos LPS + \sin LPS \cot LPS,$$

or

$$\cot p \cos P = -\sin P \cos (\alpha - A) + \sin (\alpha - A) \cdot \frac{1}{\xi}.$$

Thus

$$\xi = \frac{\sin (\alpha - A)}{\cot p \cos P + \sin P \cos (\alpha - A)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Let

$$\tan p \cos (\alpha - A) = \tan q \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Then

$$\xi = \frac{\sin (\alpha - A)}{\cot p (\cos P + \sin P \tan q)}$$

$$= \frac{\sin (\alpha - A) \tan p \cos q}{\cos (P - q)}$$

$$= \frac{\tan (\alpha - A) \sin q}{\cos (P - q)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Again in ΔkPS

$$\cot PS \sin kP = \cos kP \cos kPS + \sin kPS \cot PkS,$$

or

$$\cot p \sin (P-\phi) = \cos (P-\phi) \cos (a-A) + 0 ;$$

$$\therefore \tan (P-\phi) = \cos (a \quad A) \tan p$$

$$= \tan q.$$

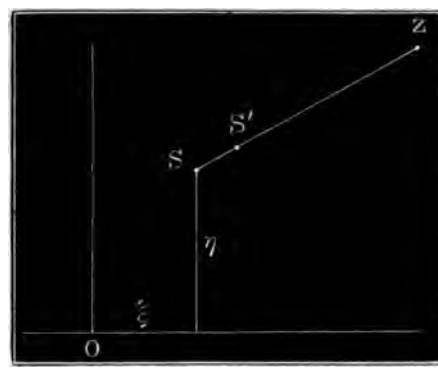
Thus

$$\eta = \tan \phi = \tan (P-q) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Formulæ 2, 3, 4, give ξ and η in terms of α, p, A, and P.

Note II.

If now S′ is a star on the plate, Z the projection of the zenith on the plane of the plate, and S be the true position of the star,



which is moved by refraction to S′ on the straight line SZ, then since SS′ is sensibly equal to its arc

$$SS' = \beta_0 \tan \angle SCZ,$$

where C is the centre of the sphere.

Now if

(X, Y) be the co-ordinates of Z,
(ξ. η) be the co-ordinates of S,

by a well-known theorem of solid geometry

$$\cos SCZ = \frac{1 + \xi X + \eta Y}{\sqrt{1+\xi^2+\eta^2}\ \sqrt{1+X^2+Y^2}}.$$

Dr. Rambaut has shown that it is only necessary to retain the first powers of ξ and η, and hence

$$\cos SCZ = \frac{1}{\sqrt{1+X^2+Y^2}} \{1 + \xi X + \eta Y\}$$

$$= \cos \theta_0 \{1 + \xi X + \eta Y\},$$

where θ_0 is the angle OCZ.

Thus

$$\tan \mathrm{SCZ} = \tan \theta_0 \{1 - \mathrm{cosec}^2 \theta_0 (\xi \mathrm{X} + \eta \mathrm{Y})\}$$
$$= \tan \theta_0 \left\{1 - \frac{\mathrm{X}^2 + \mathrm{Y}^2 + 1}{\mathrm{X}^2 + \mathrm{Y}^2} (\xi \mathrm{X} + \eta \mathrm{Y})\right\}.$$

Now the refraction resolved along ξ is

$$d\xi = \mathrm{SS}' \frac{\mathrm{X} - \xi}{\sqrt{(\mathrm{X} - \xi)^2 + (\mathrm{Y} - \eta)^2}};$$

or

$$d\xi = \beta_0 \mathrm{X} \tan \theta_0 \left[1 - \frac{\mathrm{X}^2 + \mathrm{Y}^2 + 1}{\mathrm{X}^2 + \mathrm{Y}^2} (\mathrm{X}\xi + \mathrm{Y}\eta)\right] \left[1 - \frac{\xi}{\mathrm{X}}\right] \left[1 + \frac{\xi \mathrm{X} + \eta \mathrm{Y}}{\mathrm{X}^2 + \mathrm{Y}^2}\right]$$
$$= \beta_0 \mathrm{X} [1 - (\xi \mathrm{X} + \eta \mathrm{Y})] \left[1 - \frac{\xi}{\mathrm{X}}\right]$$
$$= \beta_0 [\mathrm{X} - \xi (1 + \mathrm{X}^2) - \eta \mathrm{XY}].$$

Now $\beta_0 \mathrm{X}$ is the refraction at the centre of the plate, and hence the *differential* refraction is

$$d\xi = -\beta_0 (1 + \mathrm{X}^2) \xi - \beta_0 \mathrm{XY} \cdot \eta; \quad \ldots \ldots \quad (5)$$

Similarly

$$d\eta = -\beta_0 \mathrm{XY} \xi - \beta_0 (1 + \mathrm{Y}^2) \eta. \quad \ldots \ldots \quad (6)$$

If the photograph is taken near the meridian X will be small.

The quantities X and Y are found by the formulæ of the preceding Note: putting $\alpha = \mathrm{S}$, the sidereal time of exposure of the photograph, and $p = \lambda$, the colatitude.
Thus

$$\tan q = \tan \lambda \cos (\mathrm{S} - \mathrm{A}),$$

and can be tabulated for any given place as a simple function of the hour angle S − A. Thus:

$$\mathrm{Y} = \tan (\mathrm{P} - q)$$

is known at once, and

$$\mathrm{X} = \frac{\tan (\mathrm{S} - \mathrm{A}) \sin q}{\cos (\mathrm{P} - q)}$$

is readily found.

$1 + \mathrm{X}^2$, XY, and $1 + \mathrm{Y}^2$ can be formed quickly by Crelle's tables, three figures of decimals being amply sufficient. The magnitude of the quantities can be estimated by supposing X = 0, Y = 1, *i.e.* a photograph taken on the meridian at 45° zenith distance. Then

$$d\xi = -\beta_0 \xi;$$
$$d\eta = -2\beta_0 \eta.$$

Since ξ and η may vary from $+1^\circ \left(\frac{1}{57} \text{ in circ. measure}\right)$ to $-1^\circ \left(\text{or } -\frac{1}{57}\right)$, the corrections for refractions vary from $+\frac{1}{57}\beta_0$

to $-\frac{1}{57}\beta_0$ for ξ, and double this for η: *i.e.* (since $\beta_0 = 57''$, approximately) from $+1''$ to $-1''$, or $+2''$ to $-2''$ respectively.

Note III.

The investigation of the correction for aberration is very similar to that for refraction. If W be the projection of the

"Earth's Way" on the plate, the displacement SS′ is now proportional to sin SCW instead of tan SCZ.

Now

$$\sin \mathrm{SCW} = \sin\theta_0\,[1-\cos^2\theta_0\,(\xi X+\eta Y)].$$

Hence

$$d\xi = \gamma_0 \frac{X}{\sqrt{X^2+Y^2}} \sin\theta_0 \left[1-\frac{1}{X^2+Y^2}(\xi X+\eta Y)\right]\left[1-\frac{\xi}{X}\right]\left[1+\frac{\xi X+\eta Y}{X^2+Y^2}\right]$$

$$= \gamma_0 \frac{X\sin\theta_0}{\sqrt{X^2+Y^2}}\cdot\left[1-\frac{\xi}{X}\right]$$

$$= \gamma_0 \frac{X}{\sqrt{1+X^2+Y^2}} - \frac{\gamma_0\xi}{\sqrt{1+X^2+Y^2}}.$$

The first term is the aberration at the centre of the plate. Thus the differential aberration is

$$\partial\xi = -\frac{\gamma_0\xi}{\sqrt{1+X^2+Y^2}} \quad \ldots\ldots\ldots (7)$$

$$d\eta = -\frac{\gamma_0\eta}{\sqrt{1+X^2+Y^2}} \quad \ldots\ldots\ldots (8)$$

where γ_0 is the coefficient of aberration $= 20''{\cdot}4$ and (X, Y) is the projection of the "Earth's Way" on the plane of the plate.

Note IV.

On the Relations between the Co-ordinates of the same object on two Different Plates.

Let us first consider the relations between two sets of "Standard" co-ordinates, *i.e.* co-ordinates accurately perpendicular and

parallel to the meridian at the centre of the plate, expressed in circular measure. Let us call the two plates (1) and (2), and let the R.A.'s of their centres be A_1 and A_2, the N.P.D.'s being P_1 and P_2. Let (x_1, y_1) be the co-ordinates of a point whose R.A. and N.P.D. are (α, p) on plate (1), and (x_2, y_2) its co-ordinates on plate (2).

Then from Note I.

$$x_1 = \frac{\tan(\alpha - A_1)\sin q_1}{\cos(P_1 - q_1)}, \qquad y_1 = \tan(P_1 - q_1),$$

where

$$\tan q_1 = \tan p \cos(\alpha - A_1),$$

or more conveniently for our present purpose since

$$\tan(\alpha - A_1) = \sin(\alpha - A_1) \cdot \frac{\sin q_1}{\cos(\alpha - A_1)}$$
$$= \sin(\alpha - A_1) \tan p \cos q_1;$$

hence dividing both numerator and denominator of the expression for x_1 by $\cos q_1 \cos P_1$

$$x_1 = \frac{\tan p \sin(\alpha - A_1)\sec P_1}{1 + \tan p \tan P_1 \cos(\alpha - A_1)}$$

and

$$y_1 = \frac{\tan P_1 - \tan p \cos(\alpha - A_1)}{1 + \tan p \tan P_1 \cos(\alpha - A_1)}.$$

Thus

$$1 + y_1 \tan P_1 = \frac{\sec^2 P_1}{1 + \tan p \tan P_1 \cos(\alpha - A_1)}$$

and therefore

$$\tan p \sin(\alpha - A_1) = \frac{x_1 \sec P_1}{1 + y_1 \tan P_1};$$

$$\tan p \cos(\alpha - A_1) = \frac{\tan P_1 - y_1}{1 + y_1 \tan P_1}.$$

Thus we have, since

$$x_2 = \frac{\tan p \sin(\alpha - A_2)\sec P_2}{1 + \tan p \tan P_2 \cos(\alpha - A_2)} \text{ &c.,}$$

writing

$$(\alpha - A_2) = (\overline{\alpha - A_1} + \overline{A_1 - A_2}),$$

expanding the sine and cosine of the expression, and substituting the values of $\tan p \sin(\alpha - A_1)$ and $\tan p \cos(\alpha - A_1)$, from above,

$$x_2 = \frac{x_1 \sec P_1 \sec P_2 \cos\overline{A_1 - A_2} + (\tan P_1 - y_1)\sec P_2 \sin\overline{A_1 - A_2}}{1 + y_1 \tan P_1 + \tan P_2 (\tan P_1 - y_1)\cos\overline{A_1 - A_2} - x_1 \tan P_2 \sec P_1 \sin\overline{A_1 - A_2}}$$

and similarly

$$y_2 = \frac{\tan P_2 (1 + y_1 \tan P_1) - (\tan P_1 - y_1)\cos\overline{A_1 - A_2} + x_1 \sec P_1 \sin\overline{A_1 - A_2}}{\text{same denominator}}$$

Now let (X_{12}, Y_{12}) be the co-ordinates of the centre of plate (1) on plate (2). Then putting $x_1 = y_1 = 0$ in the above expressions we have

$$X_{12} = \frac{\tan P_1 \sec P_2 \sin \overline{A_1 - A_2}}{1 + \tan P_1 \tan P_2 \cos \overline{A_1 - A_2}};$$

$$Y_{12} = \frac{\tan P_2 - \tan P_1 \cos \overline{A_1 - A_2}}{1 + \tan P_1 \tan P_2 \cos \overline{A_1 - A_2}}.$$

Returning now to the expressions for x_2 and y_2, consider first the common denominator. Dividing throughout by the constant term $1 + \tan P_1 \tan P_2 \cos \overline{A_1 - A_2}$, which we may call D, the constant term becomes unity; the coefficient of x_1 becomes

$$(-\tan P_2 \sec P_1 \sin \overline{A_1 - A_2})/D$$

(which by comparison with the expression just obtained for X_{12} we see to be X_{21}), and the coefficient of y_1 becomes

$$(\tan P_1 - \tan P_2 \cos \overline{A_1 - A_2})/D,$$

which is thus equal to Y_{21}.

Hence the denominator becomes

$$1 + x_1 X_{21} + y_1 Y_{21}.$$

In the numerator of the expression for x_2 the constant term is, of course, X_{12}.

The coefficients of x_1 and y_1 in the numerators of the expressions for x_2 and y_2 can be simplified by the use of the quantities $X_{12}\ Y_{12}$ or $X_{21}\ Y_{21}$. The expressions for these quantities in terms of P_1, P_2, and $\overline{A_1 - A_2}$ give four equations from which P_1, P_2, and $\overline{A_1 - A_2}$ can be eliminated, leaving one relation between the four quantities X_{12}, Y_{12}, X_{21}, Y_{21}. Without performing the elimination directly it is easily seen that this relation is

$$X_{12}^2 + Y_{12}^2 = X_{21}^2 + Y_{21}^2 \quad \ldots\ldots\ldots \quad (9)$$

each side of the equation being the square of the projection of the arc joining the two centres on the tangent planes at the extremities of that arc.

Further

$$X_{12} \sin P_2 + X_{21} \sin P_1 = 0 \quad \ldots\ldots\ldots \quad (10)$$

and

$$\begin{aligned} &D(Y_{12} \sin P_2 \cos P_2 - Y_{21} \sin P_1 \cos P_1) \\ &= (\sin^2 P_2 - \sin^2 P_1) + \sin P_1 \sin P_2 \cos \overline{A_1 - A_2} \left(\frac{\cos P_1}{\cos P_2} - \frac{\cos P_2}{\cos P_1} \right) \\ &= (\sin^2 P_2 - \sin^2 P_1) D. \end{aligned}$$

Thus

$$Y_{12}\sin 2P_2 - Y_{21}\sin 2P_1 = \cos 2P_1 - \cos 2P_2 \quad . \quad . \quad . \quad . \quad (11)$$

These three relations independent of $A_2 - A_1$ are obviously all that can be obtained from the above four equations.

Again, we have

$$D = 1 + \tan P_1 \tan P_2 \cos(A_1 - A_2) = \frac{\sec^2 P_2}{1 + Y_{12}\tan P_2}$$

Thus

$$\tan P_1 \tan P_2 \cos(A_1 - A_2) = \frac{\tan P_2 (\tan P_2 - Y_{12})}{1 + Y_{12}\tan P_2}$$

$$\tan P_1 \tan P_2 \sin(A_1 - A_2) = \frac{X_{12}\tan P_2 \sec P_1}{1 + Y_{12}\tan P_2}$$

Hence in the numerator of the expression for x_2 the coefficient of x_1 is

$$\begin{aligned}&(\sec P_1 \sec P_2 \cos(A_1 - A_2))/D \\ &= \frac{\tan P_2 (\tan P_2 - Y_{12})}{\sin P_1 \sin P_2 \sec^2 P_2} \\ &= (\tan P_2 - Y_{12}) \cos P_2 \operatorname{cosec} P_1 \quad . \quad . \quad . \quad . \quad . \quad (12)\end{aligned}$$

We can give this a more symmetrical form by the use of the relation

$$\cos 2P_1 - \cos 2P_2 = Y_{12}\sin 2P_2 - Y_{21}\sin 2P_1,$$

viz.

$$\begin{aligned}&\frac{\sin P_2 (Y_{12}\sin 2P_2 - Y_{21}\sin 2P_1) - Y_{12}\cos P_2 (\cos 2P_1 - \cos 2P_2)}{\sin P_1 (Y_{12}\sin 2P - Y_{21}\sin 2P_1)} \\ &= \frac{Y_{12}\cos(2P_2 - P_2) - Y_{12}\cos P_2 \cos 2P_1) - Y_{21}\sin P_2 \sin 2P_1}{\sin P_1 (Y_{12}\sin 2P_2 - Y_{21}\sin 2P_1)} \\ &= \frac{Y_{12}\cos P_2 \sin P_1 - Y_{21}\sin P_2 \cos P_1}{Y_{12}\cos P_2 \sin P_2 - Y_{21}\sin P_1 \cos P_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)\end{aligned}$$

The coefficient of y_1 in the numerator of x_2 is

$$\begin{aligned}&(-\sec P_2 \sin(A_1 - A_2))D \\ &= -X_{12}\operatorname{cosec} P_1 \sec P_2 \cos^2 P_2 \\ &= -X_{12}\frac{\cos P_2}{\sin P_1} \text{ or } X_{21}\cot P_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)\end{aligned}$$

The coefficient of x_1 in the numerator of y_2 is

$$\begin{aligned}&(\sec P_1 \sin(A_1 - A_2))D \\ &= X_{12}\cot P_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)\end{aligned}$$

The coefficient of y_1 in the numerator of y_2 is

$$\begin{aligned}&\{\tan P_1 \tan P_2 + \cos(A_1 - A_2)\} \div D \\ &= \tan P_1 \tan P_2 \cos^2 P_2 (1 + Y_{12}\tan P_2) + \cot P_1 \cos^2 P_2 (\tan P_2 - Y_{12}) \\ &= \sin P_2 \cos P_2 (\tan P_1 + \cot P_1) + Y_{12}(\sin^2 P_2 \tan P_1 - \cos^2 P_2 \cot P_1) \\ &= \frac{\sin 2P_2}{\sin 2P_1} + \frac{1}{2}Y_{12}\{(\tan P_1 - \cot P_1) - \cos 2P_2 (\tan P_1 + \cot P_1)\} \\ &= \frac{\sin 2P_2}{\sin 2P_1} - Y_{12}\left\{\frac{\cos 2P_1 + \cos 2P_2}{\sin 2P_1}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)\end{aligned}$$

and by means of the relation

$$\cos 2P_1 - \cos 2P_2 = Y_{12} \sin 2P_2 - Y_{21} \sin 2P_1$$

this becomes

$$\frac{Y_{12} \sin 2P_1 - Y_{21} \sin 2P_2}{Y_{12} \sin 2P_2 - Y_{21} \sin 2P_1} \quad \ldots\ldots\ldots \quad (17)$$

Collecting the results, we have

$$\left.\begin{aligned} &\text{Numerator of } x_2 \\ &= x_1 \cdot \frac{Y_{12} \cos P_2 \sin P_1 - Y_{21} \sin P_2 \cos P_1}{Y_{12} \cos P_2 \sin P_2 - Y_{21} \sin P_1 \cos P_1} + y_1 \cdot X_{21} \cot P_2 + X_{12}. \\ &\text{Numerator of } y_2 \\ &= x_1 X_{12} \cot P_1 + y_1 \cdot \frac{Y_{12} \cos P_1 \sin P_1 - Y_{21} \sin P_2 \cos P_2}{Y_{12} \cos P_2 \sin P_2 - Y_{21} \sin P_1 \cos P_1} + Y_{12}. \\ &\text{Common denominator} \\ &\qquad = 1 + x_1 X_{21} + y_1 Y_{21}. \end{aligned}\right\} \quad \ldots \quad (18)$$

The expressions for the coefficients of x_1 in x_2, and y_1 in y_2, are, however, inconvenient; for when

$$P_1 = P_2, \qquad Y_{12} = Y_{21},$$

and they assume the indeterminate form $\frac{0}{0}$.

Hence when P_1 is nearly equal to P_2 they are not adapted to accurate calculation. The unsymmetrical expressions

$$\frac{\sin P_2}{\sin P_1} - Y_{12} \frac{\cos P_2}{\sin P_1}$$

and

$$\frac{\sin 2P_2}{\sin 2P_1} - Y_{12} \left\{ \frac{\cos 2P_1 + \cos 2P_2}{\sin 2P_1} \right\}$$

are better adapted for this purpose.

The above expressions are all rigorous. When P_1 and P_2 are not too small the coefficients of x_1 and y_1 in the numerators of x_2 and y_2 respectively are unity, to the first order of small quantities; and we have

$$\Delta x_2 = x_1 + y_1 X_{21} \cot P_2 + X_{12}$$
$$\Delta y_2 = x_1 X_{12} \cot P_1 + y_1 + Y_{12},$$

where

$$\Delta = 1 + x_1 X_{21} + y_1 Y_{21},$$

and all the quantities are in circular measure.

Secondly, consider the relations between actually measured co-ordinates on actual plates. These will only approximately

fulfil the theoretical conditions, owing to errors introduced by refraction, aberration, centreing, orientation, and scale values. All these should be very small, however; and if the co-ordinates $(x_1\ y_1)$ are corrected by the above formulæ they should agree very nearly with $(x_2\ y_2)$—within a few seconds of arc, say 10″. Let their corrected values be called ξ_2 and η_2.

Then

$$x_2 = (1+a)\,\xi_2 + b\eta_2 + c$$
$$y_2 = d\xi_2 + (1+e)\,\eta_2 + f,$$

where $a\ b\ c\ d\ e\ f$ are very small quantities of the order $\frac{10''}{60'}$ or $\frac{1}{360}$, whose squares and products only introduce errors of the order

$$60' \times \left(\frac{1}{360}\right)^2 = 0''{\cdot}03,$$

and may therefore be neglected. Hence if we have a chain of plates each overlapping the next, and if we first correct the co-ordinates of one by the theoretical expressions which should make them agree with those of the next, the differences between the co-ordinates of a star $x_1 - x_2$, $y_1 - y_2$ will be linear functions of x and y with very small coefficients, say

$$x_1 - x_2 = a_{12}x_1 + b_{12}y_1 + c_{12}$$
$$y_1 - y_2 = d_{12}x_1 + e_{12}y_1 + f_{12}$$

and it is easily seen that

$$a_{1n} = a_{12} + a_{23} + \ldots + a_{n-1,\,n},$$

and similarly for the other coefficients. Any system of plates which returns to the same plate thus gives us 6 equations between the experimentally determined coefficients of relation between each two.

Greenwich Mean Times of Superior and Inferior Geocentric Conjunctions of Jupiter's Satellite Callisto from 1894 *January to* 1895 *February.*

(*Communicated by the Superintendent of the Nautical Almanac.*)

The following times of geocentric conjunction of *Callisto* are in continuation of those published in *Monthly Notices*, vol. lii. p. 597, and are communicated to the Society with the view of drawing the attention of observers to the desirability of securing determinations of the positions of this satellite during the period

in which no observations of eclipses, occultations, or transits are possible.

On account of the interest and importance attaching to the first eclipses of a series, the times of superior heliocentric conjunctions of *Callisto*, occurring in 1894 December, are also given below. Assuming the accuracy of the tables, the first eclipse occurs on 1895 January 17; but it is quite possible that, owing to error in the tabular latitudes, there may be an eclipse of the satellite at one or both of the preceding conjunctions. And observers ought to be on the watch, on both these occasions, some considerable time before and after the predicted time of conjunction. The times of the corresponding inferior heliocentric conjunctions are also given, so as to enable observers to look out for the possible appearance of the shadow of the satellite on the disc on these occasions.

At the inferior heliocentric conjunction of *Callisto* on 1895 January 8, the shadow of the satellite ought, according to the tables, to fall on the disc of *Jupiter*. This first transit of shadow of the series was accidentally omitted from the *Nautical Almanac* for 1895. The following are the tabular times of ingress and egress of the shadow:—

Ingress: 1895 January 8^{d} 16^{h} 55^{m}.
Egress: 1895 January 8^{d} 17^{h} 18^{m}.

Superior Geocentric Conjunctions.

	d	h	m		d	h	m
Jan.	12	22	40·3	Aug.	2	21	30·3
	29	15	45·4		19	17	30·1
Feb.	15	9	44·7	Sept.	5	13	57·2
Mar.	4	4	37·3		22	7	42·2
	21	0	12·9	Oct.	9	1	35·7
Apr.	7	20	20·5		25	13	31·2
	23	10	31·9	Nov.	11	22	22·6
May	10	13	38·3		28	1	18·4
	27	10	34·3	Dec.	14	15	22·7
June	13	7	31·2		31	5	33·9
	30	4	24·0	Jan.	17	14	32·1
July	17	1	5·7	Feb.	2	10	33·5

Inferior Geocentric Conjunctions.

	d	h	m		d	h	m
Jan.	4	10	2·4	July	25	12	2·5
	21	5	20·4	Aug.	11	5	12·1
Feb.	7	1	32·9		28	3	53·2
	23	20	17·0	Sept.	13	22	56·8
Mar.	12	15	28·7		30	17	13·3
	29	11	18·2	Oct.	17	10	34·8
Apr.	15	7	35·6	Nov.	3	2	55·7
May	2	4	12·2		19	18	17·0
	19	1	1·1	Dec.	6	5	49·7
June	4	21	54·7		22	22	54·7
	21	18	49·2	Jan.	8	13	1·6
July	8	15	51·9		25	3	49·2
				Feb.	10	19	7·8

Superior Heliocentric Conjunctions.

	d	h	m		d	h	m
Dec.	10	13	34·5	Dec.	31	7	45·2

Inferior Heliocentric Conjunctions.

	d	h	m		d	h	m
Dec.	22	23	2·1	Jan.	8	17	6·5

1895 November 5

Observed Conjunctions of Satellite IV. with Jupiter.

By the Rev. A. Freeman, M.A.

Date.	Observed ♂.	Predicted ♂.	P−O.	Power.
1892.	h m	h m	m	
(1) Nov. 3	10 6·25	10 18·5	12·25	116
1893.				
(2) Feb. 20	6 16·1	6 22·0	5·9	165
(3) Aug. 24	13 27·75	13 37·9	10·15	80
(4) Oct. 13	15 9·2	15 12·7	3·5	116
(5) Oct. 30	8 9·5 (W)	8 17·5	8·0	116

By a conjunction is meant a position of the satellite upon the least apparent diameter of the planet, produced beyond the disc. In one case, marked (W), the position observed was upon the tangent to ♃'s disc at the west end of his equator; in this case 2 hours 25 minutes is assumed to be the interval since conjunction with the polar axis. Usually an equatorial refractor with 6½ inches aperture was employed, except on August 24, when a refractor of 3 inches aperture was used. The predictions refer to Dr. Downing's list of conjunctions in *Monthly Notices*, vol. lii. p. 597. The following distances are mere estimates. Having no clock-work I made no attempt to measure them with the micrometer. Observations on September 10, September 18, October 5, and November 7, 1893, were impeded by cloud:—

(1) From centre of IV. to north pole of ♃ was one-third of polar radius of ♃.
(2) The N. limb of IV. separated from south pole of ♃ by a diameter of IV.'s disc.
(3) The N. limb of IV. separated from south pole of ♃ by one-fourth of polar radius of ♃.
(4) Centre of IV. is south of south pole of ♃ by about one-third of polar radius of ♃.
(5) Centre of IV. is south of south pole of ♃ by about one-third of polar radius of ♃.

The following observations have been supplied to me by Mr. A. Stanley Williams, of West Brighton. They were all made by himself with the aid of his reflecting telescope, having an aperture of 6½ inches. I number them consecutively to my own, with which they may fitly be compared:—

Date.	Observed ♂.	Predicted ♂.	P−O.	Power.
1893.	h m	h m	m	
(6) Nov. 7	11 38·2	11 42·2	4·0	230
1890.				
(7) June 24	15 5·3	14 57·5	Shadow	150
(8) Aug. 30	8 32·4	8 44·5	12·1	230

The observer's own remarks are:—

(6) Clearly past conjunction 4^m after.

(7) A good observation of mid-transit of Shadow of IV.

(8) Sat. IV. appeared as a tolerably round, very dark, almost black spot.

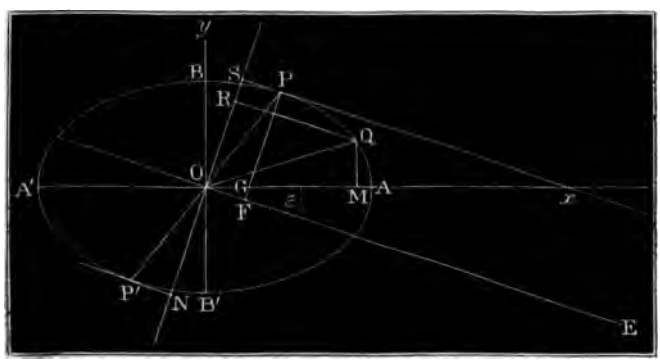
In the case of (7) and (8) the predicted times are inferred from the *Nautical Almanac* for 1890.

Murston Rectory, Sittingbourne:
1893 *November* 8.

Method of Finding the Latitudes of Saturn's Belts.

By the Rev. A. Freeman, M.A.

Numerous drawings of *Saturn* having been submitted to my inspection in the past two years, as drawn by several observers, it seems fit to show how they may be used for the purpose of determining the kronocentric latitudes of the edges of belts of the planet by measurement of the distance, taken along the central meridian, from the centre of the planet's disc to the point where the edge of any belt cuts that meridian. By this meridian is meant the line joining the apparent poles of the disc.



In the figure let the ellipse ABA^1B^1 be a section of *Saturn* by a plane passing through the Earth and the least axis of *Saturn*.

Let OE be the direction of the Earth, SPx a tangent parallel to OE, SON a straight line perpendicular to OE.

Then the apparent disc of *Saturn* is projected on the plane through SON perpendicular to OE, by straight lines in the direction of EO.

The apparent poles S, N are the projections of P and P^1.

PGF is normal to the elliptic section at P, Q is any point in this section which is projected in R upon SN, the central meridian of the disc of *Saturn*.

Let

$$\angle \text{POA} = \theta, \ \text{OP} = r,$$

then

$$\frac{\cos^2\theta}{a^2} + \frac{\sin^2\theta}{b^2} = \frac{1}{r^2}$$

if a and b are the semi-axes of *Saturn*.

Let $\epsilon = \text{EOA}$ be the elevation of the Earth north of *Saturn's* equator,

$$\text{PF} = r \cdot \sin(\theta + \epsilon) = \frac{b \cdot \sin(\theta + \epsilon)}{\sqrt{1 - e^2\cos^2\theta}}.$$

where

$$b^2 = a^2(1 - e^2).$$

Again, let

$$\text{QOA} = \phi, \ \text{OQ} = r',$$

then

$$r' = \frac{b}{\sqrt{1 - e^2\cos^2\phi}},$$

and, if OM, QM be the co-ordinates of Q,

$$\text{OM} = \frac{b\cos\phi}{\sqrt{1 - e^2\cos^2\phi}}, \quad \text{QM} = \frac{b\sin\phi}{\sqrt{1 - e^2\cos^2\phi}}.$$

Now, QR being perpendicular to OS and parallel to EO,

$$\text{OR} = \text{OM} \cdot \sin\epsilon + \text{QM} \cdot \cos\epsilon$$
$$= \frac{b\sin(\phi + \epsilon)}{\sqrt{1 - e^2\cos^2\phi}}.$$

To find the relation between θ and ϵ, by consideration of the normal at P being perpendicular to OE, we have

$$\tan\epsilon = \frac{b^2\cos\theta}{a^2\sin\theta}, \text{ or } \cot\theta = \frac{\tan\epsilon}{1 - e^2}.$$

Hence it will be possible to substitute for θ in the expression for PF, so that we shall have

$$\text{PF} = a\sqrt{1 - \cos^2\epsilon},$$

after reductions.

Thus, finally,

$$\frac{\text{OR}}{\text{PF}} = \frac{b \cdot \sin(\phi + \epsilon)}{a\sqrt{1 - e^2\cos^2\phi} \cdot \sqrt{1 - e^2\cos^2\epsilon}} \quad \ldots\ldots \quad (\text{A})$$

Now, PF is the apparent polar semi-axis of *Saturn's* disc, and OR is the distance along the central meridian to a point on it which is the projection of Q, whose kronocentric latitude is ϕ.

In 1893 the elevation of the Earth north of *Saturn's* equator ranged between 8°·802 on February 15 and 6°·093 on May 31; and it could be found from Marth's Ephemeris that the Earth's elevation was

°	d	h	
8·5 on Feb.	26	18·5	}
7·5 on Apr.	2	6·0	} . . . . . (B)
6·5 on July	5	21·0	}

In the expression (A) ϵ is positive, south latitudes answer to positive values and north latitudes to negative values of ϕ, OR being negative when R falls between O and N.

The following table, calculated by myself, gives the values of the expression (A) between south latitude 45° and north latitude 60° at intervals of 7°·5 and corresponding to the three assumed elevations (B). It will be easy by simple formulæ of interpolation to obtain from it values corresponding to the same latitudes, but to the different elevations 6°, 7°, 8°, 9°, and this will suffice for the measurement of all drawings of *Saturn* made in 1893.

We suppose

$$\frac{b}{a} = \frac{15''\cdot4}{17''\cdot3},$$

as given by Professor Oudemans (*Monthly Notices*, lii., 3), whence

$$e = 0\cdot455622$$

$$\log\left(\frac{b}{a}\right) = \bar{1}\cdot9494746, \qquad \log e = \bar{1}\cdot6586046.$$

The denominator was adapted to logarithms by assuming

$$e\cos\phi = \cos\phi_1, \text{ and } e\cos\epsilon = \cos\epsilon_1$$

Table of the Values of the Expression A.

Lat. ϕ	$\epsilon = 8°\cdot5$	$\epsilon = 7°\cdot5$	$\epsilon = 6°\cdot5$
S. 45°	+0·84671	+0·83622	+0·82530
37·5	0·76931	0·75675	0·74379
30	0·67555	0·66104	0·64626
22·5	0·56617	0·55003	0·53357
15	0·44274	0·42517	0·40741
7·5	0·30807	0·28950	0·27071
0	0·16557	+0·14631	+0·12696
N. 7·5	+0·01951	0·00000	−0·01954
15	−0·12569	−0·14505	0·16431
22·5	0·26594	0·28471	0·30336
30	0·39773	0·41558	0·43323
37·5	0·51849	0·53510	0·55146
45	0·62653	0·64166	0·65648
52·5	0·72097	0·73435	0·74746
60	−0·80145	−0·81297	−0·82418

I have extended this table to the elevations corresponding first of all to 7° and 8°, and then to the elevations, 6° and 9°, by formulæ of interpolation based on the method of *Boole's Finite Differences*, chap. iii. art. 4 of the third edition, assuming that if v_0, v_1, v_2, v_3, v_4, v_5, v_6 be the values of the expression (A) corresponding to a constant latitude ϕ, but to elevations differing by half a degree,

$$8v_2 = 3v_1 + 6v_3 - v_5 \text{ and } 8v_4 = 3v_5 + 6v_3 - v_1,$$

and finally that, third differences assumed zero,

$$v_0 = v_2 + 3(v_1 - v_2), \text{ and } v_6 = v_2 - 3(v_4 - v_5).$$

The rest of the table now follows :—

Lat. ϕ	$\epsilon=9°$	$\epsilon=8°$	$\epsilon=7°$	$\epsilon=6°$
S. 45°	+0·85179	+0·84152	+0·83081	+0·81969
37·5	0·77553	0·76305	0·75309	0·72945
30	0·68273	0·66832	0·65368	0·63878
22·5	0·57512	0·55814	0·54184	0·52522
15	0·45145	0·43398	0·41631	0·39847
7·5	0·31728	0·29881	0·28013	0·26124
0	0·17520	0·15594	0·13665	+0·11724
N. 7·5	+0·02925	+0·00976	−0·00975	−0·02937
15	−0·11769	−0·13571	−0·15456	−0·17430
22·5	0·25631	0·27534	0·29405	0·31264
30	0·38893	0·40668	0·42418	0·44273
37·5	0·51008	0·52683	0·54331	0·55955
45	0·61511	0·63538	0·64911	0·66377
52·5	0·71419	0·72769	0·74094	0·75391
60	−0·79557	−0·80725	−0·81861	−0·82968

Murston Rectory, Sittingbourne :
1893 *November* 6.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Year 1892.

By John Tebbutt.

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of *Nautical Almanac*. h m s
1892.							
Oct. 29	I.	Tr. Ingr.	Ext. contact	8-inch	230	22 10 23	
29	I.	,,	Bisection	,,	,,	22 12 23	22 10
29	I.	,,	Int. contact	,,	,,	22 13 48	
30	III.	,,	Ext. contact	,,	300	0 7 19	
30	III.	,,	Bisection	,,	,,	0 14 53	0 9
30	III.	,,	Int. contact	,,	,,	0 21 47	
30	I.	Tr. Egr.	Int. contact	,,	,,	0 18 22	
30	I.	,,	Bisection	,,	,,	0 20 7	0 22
30	I.	,,	Ext. contact	,,	,,	0 22 17	
30	III.	,,	Int. contact	,,	,,	1 49 32	2 10
30	II.	Ecl. R.	First seen	,,	140	1 58 13	1 56 5
30	I.	,,	First seen	,,	170	22 3 28	22 3 27
Nov. 14	II.	Tr. Ingr.	Ext. contact	,,	,,	21 48 12	
14	II.	,,	Bisection	,,	,,	21 50 22	21 54
14	II.	,,	Int. contact	,,	,,	21 52 41	
14	I.	Tr. Egr.	Int. contact	,,	,,	22 14 28	
14	I.	,,	Bisection	,,	,,	22 17 22	22 19
14	I.	,,	Ext. contact	,,	,,	22 19 37	
16	III.	Occ. R.	Bisection	,,	,,	22 25 9	22 35
16	III.	,,	Last contact	,,	,,	22 27 24	

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of *Nautical Almanac*. h m s
1892. Nov. 22	I.	Ecl. R.	First seen	8-inch	170	22 19 7	22 19 15
22	I.	,,	Full brightness	,,	,,	22 20 3	
23	II.	,,	First seen	,,	,,	23 1 37	23 0 43
23	II.	,,	Full brightness	,,	,,	23 4 11	
23	III.	Occ. D.	First contact	,,	,,	23 47 19	
23	III.	,,	Bisection	,,	,,	23 52 23	23 52
23	III.	,,	Disappearance	,,	,,	23 59 32	
Dec. 7	II.	,,	First contact	,,	230	23 20 40	
7	II.	,,	Bisection	,,	,,	23 22 55	23 24
7	II.	,,	Disappearance	,,	,,	23 25 24	
23	I.	Ecl. R.	First seen	4½-inch	120	0 31 30	0 31 27
23	I.	,,	Full brightness	,,	,,	0 34 0	

Remarks.

Oct. 29, 30.—Images steady and definition good; no trace of dark phase during transit of III. Eclipse of II. seen through thin cloud.

Nov. 14.—Excellent definition. II. seen as a bright spot on one of the belts 27 minutes after internal contact.

Nov. 16.—Excellent definition. Satellite small and oval, the major axis parallel to the limb of the primary.

Nov. 22, 23.—Excellent definition. At the critical moment a small filing cloud passed over II. Bisection of III. badly observed, owing to momentary bad definition.

Dec. 7.—Images tremulous and badly defined.

Dec. 23.—Sky beautifully clear; definition good, but images tremulous.

An occulting bar was not employed. The adopted longitude is $10^h\ 3^m\ 20^s{\cdot}51$ E. of Greenwich.

D

Private Observatory, Windsor, N. S. Wales:
1893 *September* 24.

Observations of the Comet Rordame-Quénisset (*b* 1893), *made at the Liverpool Observatory.* By W. E. Plummer.

The following observations were made with the Liverpool refractor of 8 inches aperture, employing either a filar micrometer or the arrangement of cross-bars recommended by Colonel Tupman, and referred to in the *Monthly Notices*, April 1893, p. 380. The references to each micrometer are the same as those mentioned in that place. With the filar micrometer the power used is 100, and with the 'reticule' either 40 or 62. The observations have been corrected for refraction in the manner suggested by the late Professor Challis. No correction has been applied for parallax. The horizontal equatorial parallax of the sun has been assumed 8″·848.

	Greenwich Mean Solar Time of Observation.				☄ − ✱ R.A.	No. of Comparisons.	Apparent R.A. of ☄.	✱ − ☄ Declination.	No. of Comparisons.	Apparent Declination of ☄.	Log Factor of Parallax (a).	Log Factor of Parallax (δ).	Star of Comparison.
1893	d	h	m	s	m s		h m s	′ ″		° ′ ″			
July	14	10	6	30	+4 26·91	10	10 12 52·83	+ 7 41·5	5	+38 36 35·6	9·6325	0·8170	*a*
	14	10	14	10	+4 32·82	Ret.	10 12 58·74	+ 6 55·3	Ret.	38 35 49·4	9·6275	0·8239	*a*
	15	10	21	15	−0 59·93	7	10 29 50·49	− 2 50·0	4	36 15 58·3	9·6178	0·8266	*b*
					−2 56·52	7	10 29 50·37	−18 28·4	4	36 15 55·8	...	...	*c*
	17	10	45	16	−3 3·98	Ret.	10 55 44·67	− 1 39·2	Ret.	31 59 13·7	9·5917	0·8431	*d*
					+0 8·42	...	10 55 44·60	+ 9 50·0	...	31 59 15·3	...	...	*e*
	20	9	22	40	−0 24·51	10	11 20 38·94	− 5 1·8	4	26 54 0·9	9·5970	0·7880	*f*
	21	9	34	41	+2 36·75	10	11 26 51·87	− 5 10·7	5	25 27 4·2	9·5923	0·8017	*g*
					+2 27·24	10	11 26 51·75	− 1 23·3	5	25 27 5·9	...	...	*h*
	22	10	11	25	−2 15·27	Ret.	11 32 20·35	−11 26·8	Ret.	24 6 38·8	9·5839	0·8286	*i*
					−2 20·72	...	11 32 20·40	− 4 4·1	...	24 6 36·5	...	...	*j*
	24	9	37	16	+1 58·00	3	11 40 53·63	− 7 8·0	3	21 51 12·2	9·5146	0·8145	*k*
	27	9	50	18	−4 41·89	Ret.	11 50 27·69	+ 9 13·3	Ret.	19 5 4·8	9·5221	0·8278	*l*
Aug.	3	9	26	0	−2 47·57	...	12 3 42·55	+ 3 1·8	...	14 39 48·7	9·5327	0·8353	*m*
					+0 44·56	...	12 3 42·69	+ 0 38·3	...	14 39 46·5	...	...	*n*
	5	9	27	42	−1 27·26	10	12 6 12·48	+ 4 13·8	5	13 43 35·0	9·5342	0·8396	*o*
	7	9	23	29	+2 40·54	10	12 8 21·90	−10 28·7	5	12 53 30·5	9·5317	0·8414	*p*
					−0 16·21	...	12 8 21·47	+ 9 0·4	...	12 53 32·2	...	...	*q*
	8	9	27	55	+0 26·71	Ret.	12 9 20·40	+ 5 28·2	Ret.	+12 30 34·6	9·5355	0·8443	*r*

Mean Places of Stars of Comparison.

Star's Designation or Authority.	Mean R.A. 1893·0.	Corr. to Apparent Place.	Mean Declination, 1893·0.	Corr. to Apparent Place.	Letter of Reference.
	h m s	s	° ′ ″	″	
Paris Catalogue, No. 12530	10 8 25·36	+0·56	+38 28 47·2	+6·9	*a*
„ „ No. 12987	10 30 39·78	+0·64	36 18 41·8	+6·5	*b*
Weisse Bessel, x., No. 609	10 32 46·24	+0·65	36 34 17·7	+6·5	*c*
Leiden Zones, 170, No. 38	10 58 47·92	+0·73	32 0 47·8	+5·1	*d*
„ „ 170, No. 34	10 55 35·45	+0·73	31 49 20·1	+5·2	*e*
Weisse Bessel, xi., No. 347	11 21 2·67	+0·78	26 58 59·2	+3·5	*f*
Paris Catalogue, No. 14042	11 24 14·34	+0·78	25 32 11·8	+3·1	*g*
„ „ „ 14044	11 24 23·73	+0·78	25 28 26·1	+3·1	*h*
„ „ „ 14245	11 34 34·83	+0·79	24 18 3·0	+2·6	*i*
„ „ „ 14247	11 34 40·33	+0·79	24 10 40·6	+2·6	*j*
Bonn Zones, vol. vi., +22°, No. 2396 ...	11 38 54·83	+0·80	21 58 18·4	+1·8	*k*
Weisse Bessel, xi., No. 1041	11 55 8·77	+0·81	18 55 50·7	+0·8	*l*
„ „ xii., No. 92	12 6 29·24	+0·78	14 36 47·5	−0·6	*m*
Bonn Zones, vol. vi., +14°, No. 2476... ...	12 2 57 35	+0·78	14 39 8·8	−0·6	*n*
„ „ „ +13°, No. 2507... ...	12 7 38·97	+0·77	13 39 22·2	−1·0	*o*
Sch. No. 4395	12 5 40 61	+0·75	13 4 0·4	−1·2	*p*
„ No. 4415	12 8 36·92	+0·76	12 44 33·1	−1·3	*q*
Weisse Bessel, xii., No. 95	12 8 52·93	+0·76	+12 25 7·8	−1·4	*r*

Notes.

July 14.—The star place differs somewhat from that given for No. 2117, zone 38° of the Bonn Catalogue.
July 15.—The comet was seen some time before a star of comparison could be seen on the light summer sky.
July 17.—Clouds interfered: the observation was not satisfactory. The condensation observed was north of the centre of the figure.
July 27.—The moon was bright, but the comet was still easily visible.
All the August observations were difficult. A haze rose from the sea and rendered observations near the horizon doubtful.

From the observations of July 14, 20 and August 3 the following orbit was computed:

Perihelion Passage, July 7, 2764 G.M.T.

ω	47° 7′ 54″·2	M. Eq. 1893.0
Ω	337 20 41·0	
i	159 57 35·2	
log q	9·829016	

From these elements an ephemeris was computed for the end of October, and a careful watch kept upon the places where the comet might be expected to be visible, but without effect.

Liverpool Observatory:
1893 *November* 7.

Observations of Brooks' Comet (c 1893), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to one another, and each inclined 45° to the parallel of declination.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

Greenwich Mean Solar Time.				Observer.	☄ − ✱ R.A.	Log Factor of Parallax.	Corr. for Refraction.	☄ − ✱ N.P.D.	Log Factor of Parallax.	Corr. for Refraction.	No. of Comps.	Appt. R.A. of ☄.	Appt. N.P.D. of ☄.	Comp. Star.
1893. d	h	m	s		m s		s	′ ″		″		h m s	° ′ ″	
Oct. 18	16	58	18	A.C.	+ 6 10·24	9·5766	+0·04	+ 7 51·8	0·8151	+0·4	1	12 24 1·63	75 55 4·2	*a*
18	17	3	47	,,	− 2 54·02	9·5754	+0·05	+ 9 26·5	0·8131	+0·5	1	12 24 1·24	75 54 38·9	*b*
18	17	3	47	,,	−15 32·07	9·5754	−0·01	− 0 58·2	0·8131	0·0	1	12 24 1·82	75 54 35·3	*c*
18	17	3	47	,,	−16 4·20	9·5754	−0·03	− 5 29·0	0·8131	−0·2	1	12 24 1·19	75 54 39·5	*d*
22	16	35	7	B.	− 4 10·97	9·5842	+0·03	+ 3 54·7	0·8135	+0·2	1	...	...	*g*
22	16	55	47	,,	+ 3 19·40	9·5801	+0·02	+ 3 50 6	0·8038	0 0	2	...	...	*f*
22	16	58	33	,,	+ 0 19·15	9·5794	+0·01	+ 2 6·6	0·8026	0·0	2	...	...	*e*
22	17	8	29	A.C.	+ 3 20·82	9·5757	+0 01	+ 3 13 6	0·7977	0·0	3	...	...	*f*
25	17	12	4	,,	− 0 0 15	9·5760	−0·02	− 6 57·2	0·7838	−0 2	5	...	...	*h*
25	17	15	29	,,	− 2 43·83	9·5744	+0·01	+ 4 40·3	0·7820	+0·1	2	12 33 37·13	71 9 43·2	*i*
25	17	15	29	,,	− 3 24·06	9·5744	0·00	+ 1 24·8	0·7820	+0·1	2	12 33 37·06	71 9 47·5	*k*
26	16	12	40	B.	− 1 3·90	9·5917	+0·05	+ 8 19 8	0·8121	+0·4	3	12 35 0·97	70 28 43·8	*l*
26	16	17	57	,,	− 0 2·08	9·5916	−0·05	− 9 20·4	0·8094	−0·4	3	12 35 0 84	70 28 47·8	*m*
30	16	28	34	,,	+ 2 6·78	9·5976	+0·02	+ 6 45·5	0·7874	0·0	3	12 41 13·48	67 31 49·5	*n*
30	16	35	58	,,	− 1 21·65	9·5956	−0·04	−15 29 5	0·7824	−0·1	3	12 41 13·07	67 31 27·8	*o*

Notes.

Oct. 30.—The Comet was fairly bright, and had a diffused nucleus. A distinct tail was seen, 15′ in length, pointing in north preceding direction. The initials A. C. and B. are those of Mr. Crommelin and Mr. Bryant respectively.

Assumed Mean Places of the Comparison Stars.

	Star's Name.	Assumed R.A., 1893·0.	Assumed N.P.D., 1893·0.	Authority.
		h m s	° ′ ″	
a	W.B. XII. 257	12 17 50·37	75 47 3·2	Lalande and Weisse's Bessel.
b	B.D. + 14°, 2512	12 26 54·26	75 45 3·0	Pulkova Catalogue, 1875.
c	W.B. XII. 632	12 39 32·99	75 55 24·5	Yarnall's Washington Catalogue, 1860.
d	W.B. XII. 646	12 40 4·51	75 59 59·7	Glasgow Catalogue, 1870.
e	B.D. + 17°, 2492	12 25 59·5	73 11 6	Bonn Observations, vol. iii.
f	Anonymous	12 28 (59)	73 14	Difference from Star *e*.
g	B.D. + 17°, 2509	12 33 30·2	73 11·5	Bonn Observations, vol. iii.
h	B.D. + 18°, 2636	12 33 34·4	71 16·4	" " "
i	W.B. (2) XII. 726	12 36 19·91	71 4 51·6	Weisse's Bessel, vol. ii.
k	W.B. (2) XII. 740, 741	12 37 0·09	71 8 11·4	" " "
l	W.B. (2) XII. 723	12 36 3·76	70 20 12·0	Lalande and Weisse's Bessel, vol. ii.
m	B.D. + 19°, 2593	12 35 1·91	70 37 57·1	Bonn Observations, vol. vi.
n	W.B. (2) XII. 774, 775	12 39 5·56	67 24 50·8	Berlin Zones, 72, 87.
o	W.B. (2) XII. 831	12 42 33·66	67 46 44·3	" " " "

Erratum in Monthly Notices, Vol. LIII. No. 5, p. 346.

Star *i* was wrongly identified; it is W.B. (2) 0, 44. 1893·0 R.A. $0^h\ 5^m\ 0^s{\cdot}55$. N.P.D. 57° 27′ 51″·7. Authorities 2nd Armagh and Paris Catalogues. The place of the anonymous star *h* (deduced from star *i*) should be 1893·0. R.A. $0^h\ 4^m\ 26^s$. N.P.D. 57° 32′.

Royal Observatory, Greenwich:
1893 *November* 8.

Errata in Mr. Stone's Paper, Monthly Notices, vol. liii. pp. 495–499.

In the collection of the results, the terms

$$\frac{m^2ee'^2}{2} - \frac{179}{144}m^4e$$

have been accidentally read into coefficient (1) instead of (2); and these coefficients therefore require correction.

The coefficient (1) should read

$$\left[1 + \frac{e^2}{2} - \left(\frac{1}{6} - \frac{355}{384}e^2 + \frac{e'^2}{4}\right)m^2 + \frac{1905}{256}m^2e^2 + \frac{331}{288}m^4 + \frac{83}{16}m^5\right].$$

The coefficient (2) should read

$$\left[-e + \frac{3}{8}e^3 - \frac{5}{192}e^5 - \frac{5}{2}e\gamma^4 + \frac{5}{4}e^2\gamma^2 + \left(\frac{11}{12}e + \frac{181}{128}e^3 - \frac{19}{32}e\gamma^2 + \frac{11}{8}ee'^2\right)m^2 + \frac{405}{64}m^3e + \frac{70027}{2304}m^4e\right].$$

Coefficient (4). In some copies, at the end of first line, for -2γ read $-2\gamma^2$.

Coefficient (78). The denominator 64 has fallen out in the press.

Coefficient (85). For $\left[-\frac{15}{8}mee'\right]$ read $\left[-\frac{15}{16}mee'\right]$.

Coefficient (104). For $\left[\frac{75}{32}mee'\right]$ read $\left[\frac{105}{32}mee'\right]$.

Erratum in Monthly Notices, vol. xlviii. p. 327.

β *Columbæ*, Proper Motion in Declination, for $-0''.06$ read $+0''.43$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. DECEMBER 8, 1893. No. 2

Captain W. de W. ABNEY, R.E., C.B., D.C.L., F.R.S., President, in the Chair.

Captain Edmond Herbert Hills, R.E., Darland House, Chatham;
Charles Herbert Edmund Rea, 223 Norwood Road, Herne Hill, S.E.; and
William Shackleton, Royal College of Science, South Kensington, S.W.,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society:—

William Ford Stanley, F.G.S., F.R. Met. Soc., Cumberlow, South Norwood, S.E. (proposed by T. Cushing).

Seventy-five presents were announced as having been received since the last meeting, including, amongst others:—

A. Auwers, Tafeln zur Reduction der Sternörtern; A. Cayley, Collected Mathematical Papers, vol. vi.; R. A. Gregory, The Vault of Heaven; W. Schur, Untersuchungen über den Verlauf der systematischen Correctionen; F. Terby, various papers on *Jupiter* and *Saturn*, presented by the Authors; A. Steinhausen, Logarithmen-Tafeln, and F. von Mocknik, Logarithmen-Tafeln, presented by General Tennant; C. Easton, La Voie Lactée, presented by Professor Bakhuyzen.

On the Cause of the per saltum *Change in the Errors of Hansen's Lunar Tables as usually compared with Observation, being an Appendix to a paper in the "Monthly Notices," vol. liv. No. 1, which exhibits these errors from* 1847 *to* 1892. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

I have recently received several inquiries on points connected with the explanation which I have given of the *per saltum* change, which certainly took place about 1864, between the tabular places given by Hansen's Lunar Tables and the corresponding observations of the Moon, when compared in the usual manner. These inquiries show that I have not yet succeeded in making my views clearly understood. I have thought it, therefore, desirable to draw up the following statement of my views, which I hope may render them at least intelligible to mathematical astronomers.

But before proceeding with these explanations, it is perhaps desirable to first call attention to the fact that if P sin $(\alpha t+\beta)$ denotes a long inequality, neither the omission of a real inequality of this form from the tabular expression of the Moon's longitude nor the erroneous introduction of such an inequality can introduce *per saltum* changes in the errors of the Tables. It will render the determinations of the values of the "epoch correction" and "mean motion" from a discussion of residuals erroneous; and it will lead, therefore, at some time or other, to progressive changes in the tabular errors for many successive years, but not to such changes in the errors of the Tables as those shown on page 10 of the *Monthly Notices*, vol. liv. No. 1.

The errors discussed in the present paper will be found to arise from the use of two independent systems of time-measures, whilst the ratio of the units is only approximately known.

In the comparisons between the theoretical and observational results of astronomy for the determination of the numerical values of the data involved, it is necessary to fix the positions of the meridian of the observer in terms of the variable, t, which is employed to fix the geocentric positions of the centres of gravity. And it becomes necessary for my purpose to discuss the accuracy with which this is effected by the methods adopted in practical astronomical work.

The "mean tropical year" referred to in my papers is that of practical astronomy; an interval of time in terms of which motions can be, and are, measured; and not any fictitious or imaginary interval of time which could not be employed for such purposes.

At the equinoxes the Sun's centre passes through the plane of the Equator, and its north polar distance is 90°.

The times by the observatory clocks of these equinoctial passages can either be directly observed at different stations on the Earth's surface, or deduced from the observations usually made. The recorded times will be subject, as usual, to errors of observation and reduction; but these errors can be confined within small limits, and will not be accumulative with the time. The intervals between successive transits of the Sun through the same equinox are the "tropical years" with which we are concerned.

The lengths of the "tropical years" can, therefore, be determined directly from observation expressed in terms of the mean sidereal day, hours, minutes, and seconds, provided the errors of the observatory clocks on the local sidereal times can be correctly determined.

The lengths of the tropical years can be corrected for secular and periodic variations from the results of mathematical investigations, in which the mean tropical year itself, or some definite part of that interval of time, is taken as the unit; and the length of the mean tropical year at the selected epoch will thus become determinable in terms of mean sidereal seconds, subject to the condition already mentioned. The interval of time which can thus be deduced from observation expressed in mean sidereal seconds is the mean tropical year with which we are concerned in practical astronomical work.

The ratio of the mean tropical year to a mean sidereal day will be absolutely independent of any particular fraction of a mean tropical year, which we may, as a matter of convenience, adopt for the "unit day"; and its numerical value can be approximated to without limit provided only the local sidereal times can be accurately deduced from observation.

The following is a general statement of the course followed to render the local sidereal times determinable from observation. It will be found that the invariability of the ratio of the mean tropical year to the mean sidereal day is a fundamental condition of the success of the methods adopted for the determination of the local sidereal times; and that no approximative value of this ratio is used in any part of the work, except in terms so small that any errors which may arise from its use will be confined within very small limits; and that such errors, if sensible, are finally eliminated from the determinations of the local sidereal times, and prevented from accumulation.

The tabular right ascensions of the clock stars are brought up from epoch in terms of the mean tropical year and some definite sub-multiple,

$$\frac{N}{2\pi} \text{ (of a mean tropical year),}$$

where N is the circular measure of some assigned angle, as convertible units of time. The fractional part of the mean tropical year thus employed as a unit in stellar astronomy is treated as the "mean solar day." These are mere statements of facts.

The local sidereal times are deduced by the aid of clocks, whose rates are steady over intervals of a sidereal day, from comparisons between the recorded clock times at the transits of the different clock-stars over the meridian and their tabular right ascensions; and, if any sensible errors exist in these local sidereal times, they are determined, and when sensible duly allowed for in practice, from direct comparisons between the local sidereal times at the transits of the Sun's centre over the meridian and the corresponding right ascensions of the Sun's centre as deduced from the observed north polar distances of the Sun and the obliquity of the ecliptic.

The result of such a process must be to entirely prevent the accumulation of error on the local sidereal times, as found from observation, due either to errors in the adopted tabular right ascensions of the clock stars at epoch; the use of slightly erroneous values of the precession constant, and of proper motions of the stars; and of any small errors due to imperfect allowances for the changes of the right ascensions of the clock-stars between the times for which they are directly computed and the times of meridian passage. The local sidereal times can thus be correctly found from observation, and they will strictly correspond to definite "mean solar times" on the scale of time-measurement adopted in stellar astronomy.

We are placed in a position to approximate without limit, by the process described, to the ratio of the "mean tropical year at epoch" to the "mean sidereal day at epoch."

If we denote the exact ratio of the "mean tropical year" to the "mean sidereal day" by

$$\frac{2\pi}{N_0}+1,$$

where N_0 is the circular measure of an angle to whose value we are continually approximating; and, if Ω denotes the mean motion in right ascension of an observer's meridian in the "unit day," equal to

$$\frac{N}{2\pi}\,.\,(\text{mean tropical year}),$$

which is adopted in stellar astronomy, we shall have

$$\Omega = 2\pi\frac{N}{N_0}+N.$$

If we knew and adopted the accurate value of N_0 to fix the proportionate part of the mean tropical year which is used as the "unit day" in stellar astronomy, we should then have

$$\Omega_0 = 2\pi + N_0,$$

and the "unit day" would, in this case, be the interval of time which astronomers have wished to adopt as their fundamental "unit day," an interval of time which, for distinction between the different "unit days" which are adopted in practice, I shall call "a physical mean solar day."

The "physical mean solar day" is the interval between consecutive transits of the meridian over the Sun's centre when cleared from secular and periodic variations, which in this case are as large proportionately to the interval of time measured as in the corresponding case of the tropical years already mentioned.

But if we adopt a definite angle N to fix the "unit day," the expression for the right ascension of the observer's meridian, A, as a function of the time, t, on the scale under consideration, assumes the form

$$2\pi\iota + A = A_0 + \left(2\pi\frac{N}{N_0} + N\right)t + \sigma t^2 + \text{nutation in R.A.},$$

where ι is an integer, A_0 and N_0 angles whose values have to be found from a discussion of these equations when formed with corresponding values of A and t.

The *exact values* of the angles

$$A_0 \text{ and } \Omega = 2\pi\frac{N}{N_0} + N$$

are unknown with the system of time measures, t, which is used in practical stellar astronomy, and which is fundamentally based upon the Sun's motion and the mean tropical year.

But in finding the local sidereal times from observation, if A_r denotes the right ascension of the observer's meridian at the time $t=r$, and $r+\delta r$ the required time when the right ascension of the meridian is A, we shall have

$$A_r = A_0 + \left(2\pi\frac{N}{N_0} + N\right)r + \sigma r^2 + \text{nut.} - 2\pi\iota$$

$$A = A_r + \left(2\pi\frac{N}{N_0} + N\right)\delta r + \sigma\,(2r\delta r + \overline{\delta r}|^2) + \frac{\delta \cdot \text{nut.}}{\delta t} \cdot \delta r.$$

The small terms

$$\sigma\,(2r\delta r + \overline{\delta r}|^2) + \frac{\delta \cdot \text{nut.}}{\delta t} \cdot \delta r$$

can be applied, if it is thought necessary, with an approximate value of δr, but they are so small that they can, in practice, be generally neglected; and we have

$$\delta r = \frac{A - A_r}{2\pi\frac{N}{N_0} + N}.$$

If we adopt for N the nearest approximative value to N_0 available at the time we shall have

$$\frac{N}{N_0} = 1 + x,$$

where x will be generally some small fraction, but may be zero; and if we adopt for A_0, as an approximative value, l, we shall have

$$A_r = l + Nr + \sigma r^2 + \text{nutation} - 2\pi(\iota - r) + \delta l + 2\pi x r;$$

and, therefore,

$$t = r + \frac{A - (l + Nr + \sigma r^2 + \text{nutation} - 2\pi(\iota - r)) - \delta l - 2\pi x r}{2\pi + N + 2\pi \cdot x};$$

or if

$$A'_r = l + Nr + \sigma r^2 + \text{nutation} - 2\pi(\iota - r)$$

$$t = r + \frac{A - A'_r - \delta l - 2\pi x r}{2\pi + N + 2\pi x}.$$

But if

$$t = r + \delta r$$

is the time which corresponds to the transit of a star, the centre of the Sun, or of the Moon, &c., over the meridian of the observer; A, the right ascension of the meridian at the time of transit, and, therefore, the right ascension of the object observed at the time

$$t = r + \delta r;$$

$\phi(t)$ the function which gives the tabular right ascension for the time; and $\delta\phi$ the true error of the tables in right ascension; we shall have

$$A = \phi(r) + \phi' \cdot \delta r + \phi'' \cdot \frac{\overline{\delta r}}{1 \cdot 2}\Big|^2 + \&c. + \delta \cdot \phi$$

where the expansion has to be carried to the required degree of approximation. We can, of course, compute the values of $\phi(t)$ for each hour

$$\phi\left(r + \frac{1}{24}\right),\ \phi\left(r + \frac{2}{24}\right) \&c.$$

and then determine

$$\phi\left(r + \frac{h}{24} + \delta t\right)$$

by expansion. We have, therefore,

$$A = \phi(r) + \phi' \cdot \frac{A - A'_r - \delta l - 2\pi x r}{2\pi + N + 2\pi x} + \&c. + \delta \cdot \phi.$$

And if, in finding the tabular right ascensions at the meridian transits for comparison with the true right ascensions, we neglect the effects of the small terms δl, $2\pi x$, we necessarily include in the differences between the observed right ascensions

and the "tabular right ascensions" the effects of the neglected terms δl and $2\pi x$ amongst those due to the errors of the Tables, $\delta\phi$; and similar remarks, of course, apply to the formation of the residual errors in N.P.D.

The importance of the errors introduced from neglecting the terms δl and $2\pi x$ will depend upon the magnitudes of the factors $\phi'(r)$, &c. In the case of the stars they will be practically insensible. But if, as is usual, we neglect the effect of these small terms in finding the tabular right ascensions a_1, a_2, a_3, . . . at the transits of the different clock-stars over the meridian of an observer on a given "sidereal day," we shall have the following exact equations of condition.

$$(1) \quad A_r + \left(2\pi\frac{N}{N_0} + N\right)\delta r_1 = \phi_1(r) + \phi_1' \cdot \delta r_1 + \&c. + \delta \cdot \phi_1 = a_1 + \delta a_1$$

$$(2) \quad A_r + \left(2\pi\frac{N}{N_0} + N\right)\delta r_2 = \phi_2(r) + \phi_2' \cdot \delta r_2 + \&c. + \delta \cdot \phi_2 = a_2 + \delta a_2$$

where δa_1, δa_2, δa_3 will denote the total corrections which the tabular right ascensions of the clock-stars require, including any which may be due to the neglect of the small terms δl and $2\pi x$. But if c_1, c_2, c_3 are the times in seconds indicated by the observatory clock at the meridian transits of the clock-stars; if we denote by c_0 the *unknown clock* time which accurately corresponds to the time $t = r$, on the scale of time under consideration; and if the "unit day" which equals the $\frac{N}{2\pi}$th part of a mean tropical year is put equal to 86400 seconds, we shall have

$$\delta r_1 = \frac{\rho\,(c_1 - c_0)}{86400}, \quad \delta r_2 = \frac{\rho\,(c_1 - c_0)}{86400}, \ \&c.,$$

where ρ will be some number which will remain constant so long as the clock has any steady rate, and the same "unit day" is adopted and put equal to 86400 seconds. We shall have, therefore,

$$(3) \quad A_r + \frac{2\pi}{86400}\left(\frac{N}{N_0} + \frac{N}{2\pi}\right) \cdot \rho\,(c_1 - c_0) = a_1 + \delta a_1$$

$$(4) \quad A_r + \frac{2\pi}{86400}\left(\frac{N}{N_0} + \frac{N}{2\pi}\right) \cdot \rho\,(c_2 - c_0) = a_2 + \delta a_2$$

$$\&c. = \&c.$$

The angle N_0 which appears in these equations is a constant, although its exact value is unknown, and N is the value assigned to the angle which is actually used in practice to fix the length of the "unit day."

If, therefore,

$$\rho\left(\frac{N}{N_0} + \frac{N}{2\pi}\right) = R,$$

R will be a constant, so long as ρ is a constant or the rate of the clock used is steady, and the same "unit day" is adopted. We shall have, therefore,

$$(5) \quad \ldots \quad \frac{A_r}{2\pi} \cdot 86400 + R(c_1 - c_0) = \frac{a_1}{2\pi} \cdot 86400^s + \frac{\delta a_1}{2\pi} \cdot 86400^s$$
$$\&c. = \&c.$$

where both sides of the equations are expressed in terms of the "mean solar seconds" of the "unit day," and from these equations values of the constants

$$\left(\frac{A_r}{2\pi} \cdot 86400^s - Rc_0\right)$$

and of R could be found. But as we require the clock errors on local sidereal time we proceed otherwise. The equivalent of the "unit day," or 86400 mean solar seconds, on the scale under consideration, in sidereal seconds is

$$86400^s \left(\frac{N}{N_0} + \frac{N}{2\pi}\right)$$

and therefore replacing the 86400 mean solar seconds by its equivalent in the equations (3); (4); &c., we have

$$(6) \quad \ldots \quad A_r + \frac{2\pi}{86400^s} \cdot \rho(c_1 - c_0) = a_1 + \delta a_1$$

$$(7) \quad \ldots \quad A_r + \frac{2\pi}{86400^s} \cdot \rho(c_2 - c_0) = a_2 + \delta a_2$$

$$\text{or } (8) \quad \ldots \quad \frac{A_r}{2\pi} \cdot 86400^s - \rho c_0 + \rho c_1 = \frac{a_1}{2\pi} \cdot 86400 + \frac{\delta a_1}{2\pi} \cdot 86400^s$$
$$\&c. = \&c.$$

where both sides of the equation are now expressed in terms of mean sidereal seconds.

The "rates" R and ρ and the corrections

$$\frac{A_r}{2\pi} \cdot 86400^s - Rc_0$$

$$\frac{A_r}{2\pi} \cdot 86400^s - \rho c_0$$

are different in the two cases, and the values which would be found for them would necessarily differ when deduced from observation. The adjustments for such changes of scale are necessarily included in the determination of clock errors and rates when accurately found from observation.

Denoting

$$\frac{A_r}{2\pi} \cdot 86400^s \text{ by } A_r^s$$

$$\frac{a_1}{2\pi} \cdot 86400^s \text{ by } a_1^s, \text{ \&c.,}$$

we have

$$(9)\quad \ldots\ldots\ldots \quad A_r^s - \rho \,.\, c_0 + \rho \,.\, c_1 = a_1^s + \delta a_1^s$$

$$(10)\quad \ldots\ldots\ldots \quad A_r^s - \rho \,.\, c_0 + \rho \,.\, c_2 = a_2^s + \delta a_2^s$$

$$\&c. = \&c.,$$

where both sides of the equations are now expressed in mean sidereal seconds.

When the equations are thus expressed in sidereal seconds we can reduce them to $0^h\ 0^m\ 0^s$ sidereal for comparison with each other and with the results found from the observations made on a consecutive "day," and thus facilitate the determination of the rate constant ρ.

If we put $\tau^s + \delta\tau^s$ for the unknown difference of time

$$A_r^s - \rho c_0,$$

which appears in all these equations, we shall have

$$(11)\quad \ldots\ldots\ldots \quad \tau^s + \rho c_1 + \delta\tau^s = a_1^s + \delta a_1^s$$

$$(12)\quad \ldots\ldots\ldots \quad \tau^s + \rho c_2 + \delta\tau^s = a_2^s + \delta a_2^s,$$

$$\&c. = \&c.$$

And, if we provisionally neglect the small errors δa_1^s, δa_2^s, and find definite values of τ^s and ρ, from the equations

$$(13)\quad \ldots\ldots\ldots \quad \tau^s + \rho c_1 = a_1^s$$

$$(14)\quad \ldots\ldots\ldots \quad \tau^s + \rho c_2 = a_2^s, \ \&c.,$$

the observatory clock when corrected by the "errors τ^s and ρ will give the "local sidereal times" as directly deduced from observation.

It will not, however, be possible to deduce the right ascension, A, of the observer's meridian accurately from the local sidereal times as thus found from the observed clock-time c by the formula

$$(15)\quad \ldots\ldots\ldots \quad A = \left(\frac{\tau^s + \rho c}{86400}\right) 2\pi$$

unless the effects of the errors δa_1^s, δa_2^s, which have been neglected in finding τ^s and ρ, are insensible.

But if $c_\odot$ is the recorded time of the Sun's transit by the clock on the "sidereal day" under consideration, and we put the Sun's right ascension, α,

$$= \frac{\tau^s + \delta\tau^s + \rho c_\odot}{86400} \,.\, 2\pi,$$

the correction $\delta\tau^s$, which the local "sidereal time" requires when found as described, can be deduced from this equation if the Sun's right ascension can be otherwise found from observation.

But if the north polar distances of the Sun's centre are

observed, the right ascensions can be found in terms of the observed north polar distances, and of the obliquity of the ecliptic. When the observations are made near the equinoxes, any small errors in the adopted value of the obliquity will not sensibly affect the resulting values of the right ascensions of the Sun thus deduced, and a mean value of $\delta\tau^s$ can thus be found. And by extending the discussion to observations of the Sun made over a year, the mean correction, $\delta\tau^s$, required by the local sidereal times found from the tabular right ascensions of the clock stars, and any correction required by the adopted value of the obliquity of the ecliptic, can be deduced from a general discussion of the equations of condition,

$$(16) \quad \frac{\alpha}{2\pi} \cdot 86400 = \tau^s + \delta\tau^s + \rho c_{\odot},$$

where α is the R.A. of the Sun's centre, as deduced from the observed N.P.D., and corrected obliquity. This is the method which is practically followed by astronomers. If the corrections $\delta\tau^s$ thus found were sufficiently large to render such a step necessary, they would have to be applied to the "local sidereal times" at once. But in the present state of astronomy the mean errors, $\delta\tau$, are so small that it is found sufficient to apply them every few years to the right ascensions of the clock-stars found from the local sidereal times

$$\tau^s + \rho c_1,\ \tau^s + \rho c_2,\ \&c.$$

In this way more accurate tabular right ascensions of the clock-stars are continually deduced and adopted for future use; and any accumulation of the effects of errors of the tabular right ascensions of the stars on the local sidereal times is thus rendered impossible.

The time, t, which, on this scale, will correspond to a given local sidereal time A^s will therefore be

$$(17) \quad t = \tau + \frac{\rho(c - c_0)}{86400 \cdot \text{unit seconds}}$$

$$= \tau + \frac{\rho(c - c_0)}{86400 \left(\frac{N}{N_0} + \frac{N}{2\pi}\right) \text{sidereal seconds}}$$

$$= \tau + \frac{(\rho c + \tau + \delta\tau) - (\rho c_0 + \tau + \delta\tau)}{86400 \left(\frac{N}{N_0} + \frac{N}{2\pi}\right)}$$

$$= \tau + \frac{A^s - A_\tau^s}{86400^s \left(\frac{N}{N_0} + \frac{N}{2\pi}\right)}$$

where the seconds are mean sidereal seconds.

The use of an erroneous value, A_τ' for A_τ^s, will necessarily

throw upon the determinations of the time, t, which correspond to a given local sidereal time A_r^s, any errors made. In fact, if we employ

$$A_r^{s\prime} = \left[\frac{l + Nr + \sigma r^2 - 2\pi(t-r)}{2\pi}\right] . 86400^s$$

instead of

$$A_r^s = A_r^{s\prime\prime} + \frac{\left(\delta l + 2\pi r \frac{N - N_0}{N_0}\right)}{2\pi} . 86400^s = A_r^{s\prime\prime} + \delta l^s + 86400^s . xr$$

we cannot escape throwing the errors made by neglecting

$$\delta l \text{ and } x = \frac{N - N_0}{N_0}$$

upon the determinations of the time, and therefore upon the epoch corrections and mean motions which are deduced from residual errors thus erroneously formed.

The exact errors of the times, t, when thus determined from the "local sidereal times" by neglecting δl and x, cannot be assigned so long as δl and x are unknown, but the differences between the errors made when using different constants, l' and N', instead of l and N, in the expression of the Sun's longitude can be computed with very great accuracy if the differences between the angles N, N', and N_0 are small. And the times, t, on the required scale can always be found from accurate observed geocentric positions of the Sun subject only to any errors which may arise from imperfect allowances for the small secular and periodic terms in the theoretical expressions of the Sun's coordinates.

The values of $A_r^{s\prime}$ are the "sidereal times at mean noon" for the standard meridian given in the Nautical Almanacs. If the "mean noons" are defined as the instants when the local sidereal time on a given sidereal day is equal to $A_r^{s\prime}$, the results are arithmetically correct. But if the usual assumption is made that $t = r$ (the value for which $A_r^{s\prime}$ is computed) when the scale of time-measurement is that which is generally adopted in practical astronomical work, the assumption will not be true unless l and N happen to have assigned to them certain definite values, l_0 and N_0; and this can only be true for one pair of such values at a given epoch. In other cases an unknown time, τ, must be introduced to transfer the "epoch" to a "mean noon" as defined.

The conclusions at which I have arrived respecting the errors made in referring the tabular places to the observer's meridian and in finding the mean solar times, t, which correspond to a given local sidereal time, A^s, follow as necessary consequences of the fact that the system of time-measures, t, in stellar astronomy is based fundamentally upon the motion of the Sun by assigning definite angles, l and N, to the epoch "con-

stant" and "mean motion" in the expression of the Sun's longitude as a function of t; and that the assigned values are not generally such that $A_0=l$; $N_0=N$. But I shall prove that not only is this the system of time-measurement adopted in stellar astronomy, but that it does not differ from the system which is adopted in gravitational astronomy unless the adopted value of the precession constant is in error, and that the two systems then only differ in the ratio

$$\frac{2\pi-P-\delta P}{2\pi-P}=1-\frac{\delta P}{2\pi-P},$$

where P is the adopted value, and $P+\delta P$ the exact value of the precessional constant referred to the mean tropical year as the unit of time.

The corrections for such differences, if sensible, can be duly allowed for at any time, as more accurate values of $P+\delta P$ become available, but these differences are altogether unimportant as compared with the differences due to the adoption of such different angles, N and N′ for N_0, as those in use before and after 1864.

It may, perhaps, avoid misconception if I point out that I am perfectly aware of the fact that it is possible to adopt other systems of time-measurement than that which I have here considered. It is possible to base our time-measures fundamentally upon the motion of the observer's meridian in right ascension by assigning definite values to the constants A_0 and Ω in the equation

$$2\pi t+A=A_0+\Omega t+\sigma t^2+\text{nutation}.$$

If we assign values

$$0,\ l,\ l' \text{ to } A_0$$
$$2\pi,\ 2\pi+N,\ 2\pi+N' \text{ to } \Omega$$

we shall have three systems of *convertible times*, t_1, t_2, t_3, where the "times" which correspond to a given right ascension, A, of the observer's meridian will be determinable from the equations

$$2\pi t+A=2\pi\,.\,t_1+\sigma_1 t_1^2+\text{nutation}$$
$$2\pi t+A=l+(2\pi+N)t_2+\sigma_2 t_2^2+\text{nutation}$$
$$2\pi t+A=l'+(2\pi+N')t_3+\sigma_3 t_3^2+\text{nutation}.$$

If either of these systems was adopted and used to bring up the tabular right ascensions of the clock stars from epoch; and if the precessional motions and proper motions were expressed in terms of the same time-scale; there would be no difficulty in

determining the "local sidereal times" from observation by following a method similar in principle to that at present adopted. Taking the second system as an illustration, we should have if

$$A_r' = l + Nr + \sigma_2 r^2 + \text{nutation} - 2\pi(\iota - r)$$

$$t_2 = r + \delta r = r + \frac{A - A_r'}{2\pi + N},$$

and the equations for the determination of times with the observatory clock would be

$$\delta r_1 = \frac{\rho'(c_1 - c_0')}{86400^s} \qquad \delta r_2 = \frac{\rho'(c_2 - c_0')}{86400^s},$$

where if the clock was the same as that before under consideration ρ' would not be the same constant, because the "unit day" of 86400^s is different, nor would c_0' be the same as c_0, because different instants of absolute time are denoted by the same number, r, on the two scales; but the equivalent of 86400 mean solar seconds in this case would be

$$86400\left(1 + \frac{N}{2\pi}\right) \text{ sidereal secs.};$$

and we should thus have from the equation

$$A_r' + (2\pi + N)\frac{\rho'(c_1 - c_0')}{86400 \text{ mean solar secs.}} = \phi_1(r) + \phi' \cdot \delta r_1 = a_1 + \delta a_1$$

$$A_r' + \frac{2\pi\rho'(c_1 - c_0')}{86400 \text{ mean sidereal secs.}} = a_1 + \delta a_1$$

or

$$A_r'^s - \rho' c_0' + \rho' c_1 = a_1^s + \delta a_1^s$$

$$\&c. = \&c.$$

The necessary adjustments between this system of time-measures and that which we have previously discussed would thus be thrown upon the clock-corrections

$$A_r'^s - \rho' c_0' \text{ and } \rho',$$

and if this method was systematically carried out, the local sidereal times could be correctly found from observation. This method would possess the advantage that the equivalent in sidereal seconds of a "unit day" would be accurately known; and if the "unit days" of practical astronomy did contain

$$86400\left(1 + \frac{N}{2\pi}\right) \text{ sidereal seconds},$$

the times found from the formula

$$t_2 = r + \frac{\rho'(c_1 - c_0')}{86400 \text{ mean solar secs.}}$$

$$= r + \frac{\rho' c_1 + \tau' + \delta\tau' - (\rho' c_0' + \tau' + \delta\tau')}{86400\left(1 + \frac{N}{2\pi}\right)}$$

$$= r + \frac{A^s - A_r'^s}{86400\left(1 + \frac{N}{2\pi}\right)}$$

would be thus correctly found.

But unless N happens to be identically equal to N_0, and l equal to a definite but unknown angle l_0, it will not be possible for $A_r'^s$ to be equal to A_r^s. It is easily seen that the intervals of time between instants marked by observational facts are correctly measured on all these systems of time-measures t, t_1, t_2, t_3, when the proper allowances are made for the different intervals of time which are in these several cases called a "day," and put equal to 86400 seconds.

For if we wish to express the interval between the instants when

$$\text{on the } \iota_0 \text{ sidereal day from epoch, L.S.T.} = A_0^s$$

and

$$\text{on the } \iota \text{ sidereal day from epoch, L.S.T.} = A^s$$

we have

$$(t - t_0)\ 86400 \text{ mean secs.} = (t - t_0)\ 86400\left(\frac{N}{N_0} + \frac{N}{2\pi}\right) \text{sidereal secs.}$$

and this is identically equal to

$$86400\ (\iota - \iota_0) + A^s - A_0^s.$$

And in the corresponding case of the system of time-measures, t_2, we should have

$$(t_2 - t_0')\ 86400 \text{ mean secs.} = (t_2 - t_0')\ 86400\left(1 + \frac{N}{2\pi}\right) \text{sidereal secs.}$$

$$= 86400\ (\iota - \iota_0) + A^s - A_0^s.$$

No errors, therefore, are made in measuring time by these different systems of time-measures, provided we do not forget that the "unit days" in the different systems denote different intervals of absolute times, and contain, therefore, different numbers of mean sidereal seconds.

It will, I hope, be thus clearly understood that I do not deny that the systems of time-measurement t_1, t_2, t_3, and others might be adopted. I simply deny, as a matter of fact, that they are exclusively adopted in practical work.

If

$$\text{a "unit day"} = \frac{N}{2\pi} \text{ (of a mean tropical year)}$$

is used, we necessarily throw away for each count, one, of the "unit day," the true sidereal equivalent,

$$86400^s\left(\frac{N}{N_0}+\frac{N}{2\pi}\right),$$

by the process employed for the determination of the errors of the sidereal clocks. If we used in practice

$$\text{a "unit day"} = 86400\left(1+\frac{N}{2\pi}\right)\text{ sidereal secs.}$$

for the determination of the errors and rates of our clocks, we should necessarily throw away

$$86400\left(1+\frac{N}{2\pi}\right)\text{ sidereal secs.}$$

as the equivalents for each count of a "unit day."

The local sidereal times of a meridian after r "unit days" on each scale are therefore necessarily different in the two cases by

$$86400\,.\,\frac{N-N_0}{N_0}\times r\text{ (sidereal secs.)}$$

and it is an allowance for the difference of this correction computed with the actual values of N and N′ adopted for N_0 before and after 1864 which accounts for the *per saltum* change in the errors of Hansen's Lunar Tables, as compared with observation when the differences

$$86400\,\frac{N-N_0}{N_0}\,.\,r$$

and

$$86400\,\frac{N_1-N_0}{N_0}\,.\,r$$

are neglected.

But even if it were true that the times as found from observation were on the scale of time-measurement, t_2, it would not be generally true that these are the times required for the accurate determination of the constants contained in the differential equations and their integrals which represent the positions of the planets; and they would not, therefore, be the times required in practical astronomical work.

The general principle involved in these questions of time-determination is that definite values have to be assigned to some epoch correction, $n\tau$, and to some mean motion, n, in one of the theoretical expressions which represents a motion, which can be compared with the results of observations to render the time, t, observationally determinate.

The selection of a particular motion for this purpose is merely a question of practical convenience. The adoption of the mea-

sures t_1, t_2, or t_3 would simplify the direct determinations of the time from observation, but would greatly complicate the mathematical investigations of gravitational astronomy; and this is the reason why they have not been exclusively adopted.

The differential equations of motion are formed on the assumed truth of Newton's law of universal gravitation, "that every particle of matter in the universe attracts every other particle with a force which is proportional to the mass of the attracting particle directly and to the square of the distance between the particles inversely."

The law thus generally stated is, however, of no practical value, as a basis of mathematical investigation, until we have defined how the masses are to be measured, and the relationship between the force of gravitation, the mass, and the distance practically established.

If we assume that the law of gravitation is true when the masses are directly measured by their accelerating effects, the law becomes available as a basis of calculation, and it is upon this assumption that the differential equations of motion used by astronomers are formed; but it will be found that when the masses are thus measured the measures themselves are not independent of the units of time and of space which are adopted, but change their numerical values with changes of these units; and if, to avoid this inconvenience, we agree not to measure "masses" by their accelerating effects, but to take the "mass" of the Sun as "the unit of mass," and denote the masses of the planets *Mercury*, *Venus*, *Earth*, &c., by the fractions

$$\nu_1, \nu_2, \nu_3, \text{ \&c.}$$

which express the ratio of their "masses" to that of the Sun, so that the masses

$$1, \nu_1, \nu_2, \nu_3, \text{ \&c.}$$

are independent of the adopted units of length and time, it will be found necessary, before we can form the differential equations of motion of the planets, to introduce a factor, f, such that

$$f \cdot 1, f \cdot \nu_1, f \cdot \nu_2, f \cdot \nu_3, \text{ \&c.}$$

will denote the accelerating effects of the respective masses. And, in this case, the numerical values which will have to be assigned to the factor f will depend upon the particular units of time and of length which we may adopt.

The factor f, when thus introduced, never appears in our equations unless multiplied by one of the masses

$$1, \nu_1, \nu_2, \nu_3, \text{ \&c.}$$

and, conversely, a "mass"

$$1, \nu_1, \nu_2, \nu_3, \text{ \&c.}$$

never appears in these equations unless multiplied by the factor f or as a ratio to other masses.

And it will be imposible, therefore, to correctly determine the numerical values of the fractions

$$\nu_1, \nu_2, \nu_3, \text{ \&c.}$$

from the accelerating effects produced by the masses

$$f \cdot 1, f \cdot \nu_1, f \cdot \nu_2 f \cdot \nu_3, \text{ \&c.}$$

unless the factor f has the same numerical value assigned to it in all our mathematical expressions, or unless any changes in the values adopted for f are accurately allowed for in evaluating the accelerating effects produced by the different masses.

The differential equations of motion for the different planets, the Moon, and for the rotation of the Earth about its axis are not isolated systems of three equations, but coexisting simultaneous equations.

And since the same symbols appear in many of these equations to represent the same physical quantities, it is absolutely necessary, in order that the results found from the integration of one set of equations may be transferable to the others, that the same units of length and of time should be adopted in the formation of all the equations of motion; or if different units are employed in special investigations, that all the physical quantities should be transferred to common units before they are used for the formation of any set of differential equations. And this will require that the ratios of the different units employed should be accurately known.

There is absolutely nothing to restrict our selection of units of time and of length in the mathematical investigations of astronomy, so long as no numerical value is assigned to f, and they are conducted in a purely symbolical form, and without the introduction *of any conditions which can only be satisfied by the adoption of particular units of time and length.* But to speak of the variable t in such cases as denoting "mean solar time" is nomenclature devoid of any physical significance. And if we adopt for the unit of time either the "mean sidereal day" or the "physical mean solar day," and for unit of length "a statute mile," "ninety-two millions of statute miles," or "the equatorial radius of the Earth"—units in terms of which the exact numerical value of the factor f is unknown—we shall have to overcome the mathematical difficulties which will arise from the appearance of an unknown factor, f, to all the measures of mass in our expressions.

But if $f_0 \times 1$ denotes the accelerating effects of the Sun's mass at the unit of distance in the unit of time, when such definite units as those described are adopted; and $f \times 1$, the value when units which bear to the former the ratio $1+p$, $1+q$ respectively

are adopted, it can be directly proved by a simple change of the variables in the differential equations of motion that

$$f = \frac{f_0(1+q)^2}{(1-p)^3} \text{ identically.}$$

If, therefore, we adopt for f_0 an approximate value, f', it matters not in the slightest degree how f' may have been found, or why we have adopted it; we must, in order to correctly form the differential equations of motion in terms of definite units of length and of time, such as those above mentioned, substitute for f_0 its value

$$f' \cdot \frac{(1-p)^3}{(1-q)^2},$$

where $1+p$ and $1+q$ will denote the ratios of units of length and of time, for which the accelerating effects of the Sun's mass is equal to f', to the definite units of length and of time in terms of which we propose to express all the linear and time-quantities found from observation, and to determine the numerical values of the constants which appear in our integrals.

If we put $p = 0$ and $q = 0$ and form the differential equations of motion with the definite value f', then if our mathematical work is accurate, and Newton's law of gravitation is true, the resulting integrals of the differential equations of motion will express the coordinates required in terms of such units of length and of time that for these units f' exactly equal the Sun's accelerating effects at the unit of distance in the unit of time; but not in terms of the definite units of length and time in terms of which we proposed to express our linear and time quantities.

If we resist, therefore, upon the adoption of such definite units as those of the equatorial radius of the Earth and the "mean solar day" or the "sidereal mean solar day," we shall have, when using a definite value, f' for f_0, to retain in all our equations of motion, and throughout all our mathematical work, the expression

$$f' \cdot \frac{(1-p)^3}{(1-q)^2}$$

for f_0, and when we have succeeded in establishing exact relations between

$$f' \cdot \frac{(1-p)^3}{(1-q)^2}$$

and some linear quantity and some interval of time determinable from observation in terms of the several units of length and of time, we shall be able to determine the numerical values of p and q, and to derive the required value

But the numerical values of the numbers p and q, found

in this way from a discussion of observations would be liable not only to fallible errors of observation but to serious systematic errors if any long inequalities

$$\mathrm{P} \cdot \sin(\alpha t + \beta)$$

with sensible coefficients, P, were neglected in the theoretical expressions compared with the corresponding results from observation. For in such cases

$$\mathrm{P} \cdot \sin(\alpha t + \beta) = \mathrm{P} \cdot \sin\beta + \alpha t \cdot \mathrm{P}\cos\beta - \frac{\alpha^2 t^2}{1.2} \cdot \mathrm{P}\sin\beta \quad . \quad . \quad . \quad \&c.$$

and the effects of the terms

$$\mathrm{P} \cdot \sin\beta\,;\ \mathrm{P}\alpha \cdot \cos\beta, \&c.,$$

would be thrown upon the determinations of the epoch corrections and mean motions, and, therefore, upon the determinations of p' and q', and of

$$f_0 = \frac{f'(1+p')^2}{(1+q')^2},$$

and the approximate values of f_0 thus found would be liable to systematic errors which would not even be constant but subject to determinate laws when found for different epochs, and from observations extending over different intervals of time. It is unnecessary to point out that the mathematical difficulties presented by the problems of physical astronomy would be enormously increased from the causes indicated if such definite units of time and of length were adopted. In such cases we should be practically replacing in our mathematical work the fundamental constant, f_0, by a quantity which was a complicated function of the time.

It is possible, however, to avoid these mathematical difficulties with respect to variations in the adopted values of f by the selection of suitable units of length and of time; but if such units are selected to render f definite, then for accuracy all the linear quantities and time-quantities, which enter into our equations must be determined in terms of the same units as those for which f expresses the accelerating effects of the Sun's mass at the unit of distance in the unit of time; and if the unit of time is not equal

$$86400 \text{ sidereal seconds } \left(1 + \frac{\mathrm{N}}{2\pi}\right),$$

then the use of the times t_2, found from the equation

$$2\pi\iota + \mathrm{A} = l + (2\pi + \mathrm{N})\, t_2 + \sigma t_2^2 + \text{nutation}$$

would certainly lead to error.

In fact, in these and other similar cases, the simplifications introduced in one stage of the work by the selection of particular

units are to some extent counterbalanced by additional complications introduced in the other parts of the work.

We shall next consider how the factor f, which is used in gravitational astronomy, is connected in practice with measures of time and of length, which fix the units in terms of which it will measure the accelerating effects of the Sun's mass at the unit of length in the unit of time, if Newton's law of gravitation is true. The conditions which are made use of in practice to fix the value of f are from the positions of the observing stations almost necessarily directly connected with the Sun's geocentric motion.

If the constants introduced in the integration of the differential equations which result from the neglect of the disturbing masses in the differential equations of the Sun's geocentric motion are denoted by a, e, ω, τ, Ω, and γ; and we denote by $a+\delta a$, $e+\delta e$, &c., the functions which when substituted for a, e, &c., in the expressions

$$\mathrm{R}\,.\cos \mathrm{L}\,.\cos\lambda = \mathrm{R}\,[\cos v\,.\cos\Omega - \sin v\,.\sin\Omega\,.\cos\gamma]$$

$$\mathrm{R}\,.\sin \mathrm{L}\,.\cos\lambda = \mathrm{R}\,[\cos v\,.\sin\Omega + \sin v\,.\cos\Omega\,.\cos\gamma]$$

$$\mathrm{R}\,.\sin\lambda = \mathrm{R}\sin v\,.\sin\gamma,$$

where

$$\mathrm{R} = a\,(1-e\cos\phi);\quad \tan\frac{v-\omega}{2} = \sqrt{\frac{1+e}{1-e}}\,.\tan\phi$$

$$\phi - e\sin\phi = \sqrt{\frac{f'^2\,(1+p')^3}{(1+q')^2}}\,.\,(t+\tau)$$

satisfy the differential equations of the Sun's motion, and the three subsidiary equations usually introduced to render the six functions

$$a+\delta a,\ e+\delta e,\ \&c.,\ \text{determinate},$$

it is found that the geocentric longitude, L, and the distance, R, will be expressed under the forms

$$2\pi\iota' + \mathrm{L} = \sqrt{\frac{f'^2(1+p')^3}{a^3(1+q')^2}(1+\nu_3)}\,.\tau(1+\delta\tau) + \sqrt{\frac{f'^2(1+p')^3}{a^3(1+q')^2}(1+\nu_3)}\,.(1+\delta\mathrm{P})\,.\,t$$
$$+(2e_1 - \quad)\,.\sin\zeta + \&c.$$

$$\mathrm{R} = a\,(1+\delta\theta)\left[1+\frac{e_1^2}{2} - (e_1 - \quad)\,.\cos\zeta + \&c.,\right.$$

where

$$e_1 = e\,(1+\delta\phi)$$

is a constant, and ι' is an integer.

The symbols $\delta\tau$, $\delta\mathrm{P}$, $\delta\theta$, and $\delta\phi$ denote collections of small terms independent of the time which all contain, one or more, of the disturbing masses as a factor. The geocentric longitude, L, is here supposed to be measured from a fixed initial time.

If p' and q' have the numerical values assigned to them which renders the equation

$$f_0 = \frac{f'(1+p')^2}{(1+q')^2}$$

exact with the adopted value, f', when the unit of length is the mean equatorial radius of the Earth, and the unit of time an interval which contains

$$86400\left(1+\frac{N}{2\pi}\right) \text{ sidereal seconds,}$$

and if D denotes the mean distance of the Sun from the Earth, expressed in terms of the adopted unit of length, and n_s, l_s, the exact values, on the scale of time-measurement adopted, of the mean motion and epoch correction, we shall have

$$\sqrt{\frac{f'(1+p')^2}{(1+q')^2}\cdot\frac{1+\nu_s}{a^3}}\cdot(1+\delta P)=n_s \qquad n_s\cdot\frac{\tau(1+\delta\tau)}{1+\delta P}=l_s$$

$$D=a\,(1+\delta\theta)\left[1+\frac{e_1^2}{2}\right].$$

But if n is the Sun's mean motion in the interval of time which contains

$$(1+q')\,86400\left(1+\frac{N}{2\pi}\right) \text{ sidereal seconds,}$$

or in the interval for which, when adopted as the unit of time, f' is the exact value of the Sun's accelerating effects at the distance of the equatorial radius of the Earth, we shall have

$$n=n_s(1+q'),$$

and if we adopt the interval of time,

$$(1+q')\,86400\left(1+\frac{N}{2\pi}\right) \text{ sidereal seconds}$$

as the unit of time, instead of

$$86400\left(1+\frac{N}{2\pi}\right) \text{ sidereal seconds,}$$

we directly eliminate the factor $(1+q')$ from our equations. In this case we have

$$\sqrt{\frac{f'(1+p')^2}{a^3}}\cdot(1+\nu_s)\cdot(1+\delta P)=n;$$

but when this method is adopted, directly a value is assigned to n in the expression for the Sun's longitude, the unit of time is absolutely fixed; it will in this case be the

$$\frac{n}{2\pi} \text{ part of an interval of time, } \sigma,$$

where σ is generally called by astronomers the mean sidereal year.

Again, since

$$\sqrt{\frac{f'^2(1+p')^3}{a^3(1+q')^2}} \cdot (1+\nu_3) \cdot \tau\,(1+\delta\tau) = l_0 = \frac{n\tau\,(1+\delta\tau)}{1+q'} = n\tau',$$

where τ' is an interval of time measured on the new time-scale, we can change the "epoch" or instant from which t is measured by putting

$$\tau' = \frac{l}{n},$$

where l is some assigned angle.

The times t then become determinate from the equation

$$2\pi t' + \mathrm{L} = l + nt + (2c' \quad) \cdot \sin\zeta + \&c.$$

But we can further simplify the expression for the factor f, which expresses the accelerating effects of the Sun's mass at the unit of distance in the unit of time by adopting a suitable unit of length.

If we denote by D′ the number which expresses the mean distance of the Sun in terms of a unit which equals

$(1+p')$ times the equatorial radius of the Earth,

we shall have

$$\mathrm{D}'(1+p') = \mathrm{D} = a\,(1+\delta\theta)\left[1+\frac{e_1^2}{2}\right],$$

and

$$\sqrt{\frac{f'}{\mathrm{D}'^3}} \cdot (1+\nu_3)\,(1+\delta\theta)^{\frac{3}{2}}\left(1+\frac{e_1^2}{2}\right)^{\frac{3}{2}}(1+\delta\mathrm{P}) = n.$$

If, therefore, we take the unit such that

$$\mathrm{D}' = (1+\nu_3)^{\frac{1}{3}}(1+\delta\theta)\left(1+\frac{e_1^2}{2}\right)(1+\delta\mathrm{P})^{\frac{2}{3}},$$

we have

$$\sqrt{f'} = n,$$

and, conversely, if we adopt n, the coefficient of t, in the expression of the Sun's geocentric longitude to fix the value of $\sqrt{f'}$, and assign a definite value to

$$l = n\tau\,\frac{(1+\delta\tau)}{1+\delta\mathrm{P}},$$

the mathematical results obtained from the integration of the differential equations of motion when complete, or sensibly complete, will give the true coordinates of the Sun, Moon, &c., when the linear and time-quantities which they contain are all expressed in terms of the units of time and of length thus fixed. But the times t must in such cases be necessarily found subject to the condition

$$2\pi t' + \mathrm{L} = l + nt + \&c., \quad . \quad .$$

where n is the angle adopted to fix the value of $\sqrt{f^1}$; or if the longitude L′ is measured from the equinox, we shall have

$$2\pi\iota' + \mathrm{L}' = l + (n + p + \delta p)\, t + \&c.,$$

where p is the adopted value, and $p + \delta p$ the true value, of the precessional motion on the scale of time-measurement under consideration. Comparing this with the expression adopted in stellar astronomy,

$$2\pi\iota' + \mathrm{L}' = l + (n + p)\, t',$$

it follows that the time-scale adopted in stellar astronomy is not identically the same as that required unless $\delta p = 0$; but the differences are insignificant as compared with the differences between the times t, t_1, t_2, t_3, &c., and the necessary corrections can be easily and directly applied at any time if the error δp is found to be sensible.

But instead of fixing the unit of length in the way described, the following method is in practice more convenient, as it is generally employed in the deduction of the geocentric coordinates from the heliocentric coordinates.

Let the number p' be so selected that with the unit of length

$$(1 + p') \times \text{equatorial radius of the Earth.}$$

$$\mathrm{R}' = \frac{a}{1 + p'}(1 + \delta\theta) \cdot \left[1 + \frac{e_1^2}{2} - (e' - \quad) \cos\zeta + \&c.\right]$$

becomes

$$\mathrm{R}' = 1 + \frac{e_1^2}{2} - (e' - \quad) \cos\zeta + \&c.$$

We then have

$$a = \frac{1 + p'}{1 + \delta\theta};$$

and the equation

$$\sqrt{\frac{f'(1 + p')^3}{a^3}(1 + \nu_3)(1 + \delta\mathrm{P})^2} = n$$

gives

$$f' = \frac{n^2 \cdot a^3}{(1 + p')^3 (1 + \nu_3)(1 + \delta\mathrm{P})^2} = \frac{n^2}{(1 + \nu_3)(1 + \delta\mathrm{P})^2 (1 + \delta\theta)^3}$$

$$= n^2 \frac{a^3}{1 + \nu_3} \quad \text{or} \quad n^2 \mathrm{a}_1^3,$$

where

$$\mathrm{a} = \mathrm{a}_1 (1 + \nu_3)^{\frac{1}{3}} = (1 + \delta\mathrm{P})^{-\frac{2}{3}} (1 + \delta\theta)^{-1},$$

where a and a_1 will be linear quantities whose exact ratios to the adopted unit can only be found from the mathematical inves-

tigations conducted in terms of the unit of length thus fixed and with times, t, subject to the condition

$$2\pi\iota' + \mathrm{L} = l + nt + \&c.,$$

or

$$2\pi\iota' + \mathrm{L}' = l + (n + p + \delta p)t + \&c.,$$

when n has assigned to it the same numerical value as that employed in fixing the value of $\sqrt{f'}$.

The equatorial radius of the Earth must in such cases be expressed in terms of the adopted unit of length; but this presents no difficulty, for its numerical expression is not required when the equatorial horizontal parallaxes are introduced.

Any errors made in fixing the positions of the meridians in terms of the variable, t, due to the neglect of sensible corrections

$$\delta l \text{ and } x = \frac{\mathrm{N} - \mathrm{N}_0}{\mathrm{N}_0}$$

will appear, from reflex action, as apparent corrections (but they will be mixed up with the effects of any neglected long inequalities), to the adopted epoch constant, l, and mean motion, n, in the expression of the Sun's longitude. We shall thus be able to ultimately determine the corrections δl and x; but the effects of these errors will be much larger in the case of the Moon than in the case of the Sun during the progress of the approximations; and the errors thus introduced are not due to errors of gravitational theory, but to errors in the determination of the time.

This completes the proofs which are required to establish the necessity of the corrections which I have indicated in fixing the relative positions of the centre of gravity of the Sun and of the positions of the meridians in terms of the measure of time, t, which is adopted in practical astronomical work.

It has been shown that the system of time-measures adopted in gravitational astronomy is based on the geocentric motion of the centre of gravity of the Sun; that, subject to the possible small correction for error δp, the same system is adopted in stellar astronomy; that the local sidereal times are correctly found with this system of time-measures; but that errors are made in fixing the position of the meridian in terms of t or in finding the time on the required scale from the local sidereal times; and that these errors enter directly in the work in referring the tabular positions to the meridian for a comparison with the local sidereal times; and the "Tables" which I have given (*Monthly Notices*, vol. liv. No. 1) show that the differences thus made, before and after 1864, account for the *per saltum* change of the errors of the Tables which undoubtedly took place about 1864.

On Errors that may arise in Estimating Star Magnitudes by Photography. By Captain W. de W. Abney, C.B., R.E., D.C.L., F.R.S.

In a recent paper read before the Photographic Congress held in October last I gave my results of experiments carried out with a view of investigating the interdependence of time of exposure and intensity of light. I found that when very feeble intensities of light were allowed to act for times proportionately longer than when a greater intensity was employed, so that in all cases the product of intensity and time were the same, the chemical action, or in other words the density, produced was by no means the same under certain conditions of sensitive surface. Now, I have often expressed the opinion that it should be the same, but have guarded myself by adding within limits. For instance, five years ago, when President of Section A of the British Association, I stated this more explicitly.

I refer to this to justify myself against the charge of being inconsistent. I may also say that at the Paris conference on the stellar photographic map it was my intention to indicate the same, but I honestly say I was not prepared for such a break-down of the usually accepted law under some of the conditions under which the experiments were undertaken. The condition for a break-down is this, that if a slow plate be used—more particularly, I believe, if it be one which is a pure bromide—the products of time and intensity being a constant do not always give the same amount of chemical action. Now, this is a serious matter for the star-charts which are being prepared in accordance with the plans laid down at astro-photographic congresses, for it by no means follows that star magnitudes will always be the same when derived from different plates. I will show you a few examples on the screen of the results of the experiments made. In the first we have an example of a fairly rapid plate, which was exposed at varying distances from an amyl acetate lamp, with increased exposures for increased distances, so that the aforesaid product in every case was the same. It will be seen that the feebler the intensity of the light, the less the chemical action. The next slide shows this graphically, the transparency being measured from the negatives. It will be noticed that, in the case of the plate shown, when the intensity of the light is reduced to $\frac{1}{256}$, the apparent chemical action is only about $\frac{1}{4}$ what it should be, according to the ordinary assumption. The next slide gives the results in the shape of a table. Now let us apply this to the star magnitudes. Suppose such a plate be exposed so as to impress, say, a star of the 7th magnitude in a certain number of seconds; we should expect that to get one of the 11th

magnitude we should have to expose for an equivalent number of seconds. Yet if we gave that exposure we should find that we had impressed the image of a star no brighter than one between the 9th and 10th, since what I call the equivalent exposure would not be more than $\frac{1}{4}$ what it would be expected to be. If this be the case, it is evident that any star magnitudes which were obtained would be untrustworthy, unless special precautions were taken, which I can indicate briefly. The scale of gradation of a plate when exposed for the same time to varying intensities of light at the same time is altered, as I can show you by plates exposed in a sensitometer. For instance, we have two plates—one of the same make already shown, and the other a very rapid plate—the number of gradations as shown by the squares which have been acted upon by properly graduated intensities of light were fewer in the first case than in the second. Now, the last visible square in each may be supposed to represent the faintest light that would make an impression in the given time, so that if exposures with both of them were given for times which would impress them with the star-disc of, say, a 1st-magnitude star of a certain diameter, the limit of higher magnitude stars which would be impressed would differ considerably. If we take it that in one case stars from the 1st to the 11th magnitude, and in the other stars from the 1st to the 7th magnitude, were shown (the diameters of the star discs of the 1st-magnitude star being the same in both cases), then the diameters of the star discs of the 6th magnitude on the one plate and of the 4th on the other would be very approximately the same, supposing they lie in the part of the curve which descends in the straight part of the curve. In other words, there would be a proportional diminution in the diameters of the star discs in the latter plate. If, then, the discs of two stars largely differing in magnitude but lying within the limits indicated be determined, those of the others may also be determined, supposing a formula for decrease in diameter with increase in magnitude has previously been arrived at. It must, however, be recollected that there are portions of the curve which are beyond the limits indicated, and here any comparison would fail. There is, however, one comfort, which is that a very rapid plate shows less deviation from the assumed law than a slower one; in fact, the more rapid the plate, the less the deviation that will be shown. Further, I have come to the conclusion that the composition of the sensitive surface has much to say to the results. I wish to guard myself against any rigid expression of opinion on this subject, as my experiments are as yet incomplete, but I fancy that a homoiodide plate will be found to have less deviation from the assumed law than a homobromide. Those who are interested in the subject know that there have been many curious differences in the star magnitudes as derived from a

plate, and some observers have found that the time of exposure necessary to impress a higher magnitude star is greater than that which theoretically should be the case, and it seems probable that this result is due to the difference in behaviour of the plates used. It will probably turn out that each particular brand of plate will require a different formula for arriving at star magnitudes photographically, and that the formula which is suitable for one will not be suitable for another. I should like, in conclusion to this note, to point out a method by which an idea as to the suitability of a plate for stellar work can be obtained. In the investigations to which I have referred I also included the effect of a number of small exposures succeeding each other with varying rapidity, and I found that *the sum of a large number of small exposures was not equal to the same exposure given at one time*, and whether a plate were slow or rapid, it showed a break-down of the assumption usually made that such should be the case. Further, it was found that the longer the interval of rest between successive exposures the less the chemical action. The more rapid the plate the less this loss of energy appeared; in fact, it followed the rule found when the intensity of light was diminished. The plate placed in the lantern shows this, and the next slide shows the curve derived from it. It will be noticed how the chemical action falls off, whatever be the exposure.

Now, this affords a ready means of testing a plate, for if it fails largely with this test, it will fail also, to a certain extent, with the other. If a lamp of 1-candle power be placed at such a distance from the plate that 20 seconds' exposure gives a medium density to a portion of the plate, the remainder being covered up, and a sector with a 20° aperture be rotated in front of the beam some ten to twenty times a second for 360 seconds, a different part of the plate being exposed, then, should the densities given by the two exposures be within ·7 of one another, the plate may be considered practically to obey the usually assumed law, and star magnitudes can be obtained from all such plates, as the times of exposure for obtaining higher magnitudes will very closely coincide with those which are theoretically required.

The Secondary Colour Aberrations of the Refracting Telescope in Relation to Vision. By H. Dennis Taylor.

It is notoriously easy to grow so accustomed to a supposed necessary evil as to become practically oblivious of its presence. The astronomer who diligently uses his refracting telescope ceases to notice the ever-present halo of purplish light which surrounds the objects of his scrutiny, and is somewhat startled,

or even offended, when some brother astronomer, accustomed to use his reflecting telescope, takes a look through the refractor, perhaps for the first time, at a planet or a star, and recoils with an expression of surprise at the unsightly amount of coloured fringe which he sees. And, certainly, to one who sees it for the first time and has always heard the refractor spoken of as *achromatic*, the secondary spectrum seems far too aggressive a fault to be ignored.

Much has already been written about the secondary spectrum of the refracting telescope, but, I venture to think, to relatively little practical purpose.

The theory of vision through the refractor has, so far as I know, never yet received adequate attention. At the same time, the production of an objective practically as achromatic as the reflector has in many quarters been looked upon as a mere refinement, because the very serious nature of the secondary colour aberrations of ordinary objectives, especially when their apertures are measured by feet, has not been sufficiently realised. I will now proceed to give what seems to me sufficient evidence of the detriment and loss of utility suffered by the larger refractors owing to the imperfect nature of their achromatic corrections.

Plate 1 illustrates the secondary colour aberrations of the refracting telescope in the form of graphic curves.

First of all, in fig. 1 is shown the colour curve of the great Lick refractor as plotted out from the actual measurements of the foci for the various colours, executed with great care by means of a large spectroscope by Mr. James Keeler.*

The great objective is so corrected that the two rays, B and F, come to exactly the same focus, which is taken as the zero in the following table, where the colour aberrations are preceded by a + sign when the respective colours focus beyond the focus for B and F, and by a — sign when they focus short.

TABLE I.

Lick Refractor. Focal Length = 57 feet.

Wave-length.	Fraunhofer line.	Distance of foci from focus for B & F. Inches.
·6867	B	0·00
·6562	C	−0·24
·5889	D	−0·45
About ·5650	Minimum focus	−0·47
·4861	F	0·00
·4341	G′ or Hγ	+1·45
·4101	*h*	+2·76
	Visual focus	−0·20

* *Publications of the Astronomical Society of the Pacific*, Nov. 9, 1890.

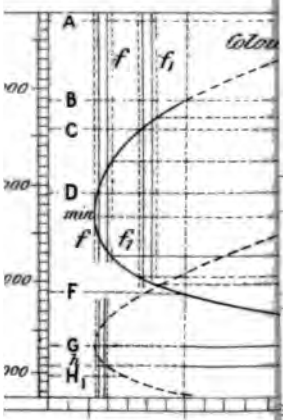


FIG. 5.

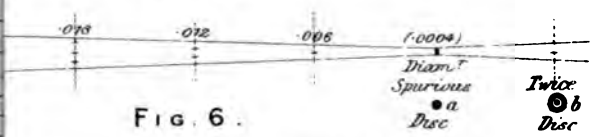
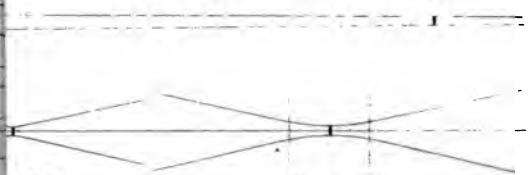


FIG. 6.



7a

FIG. 7b

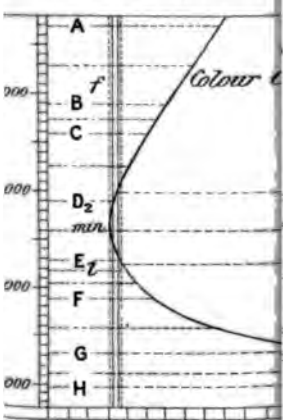
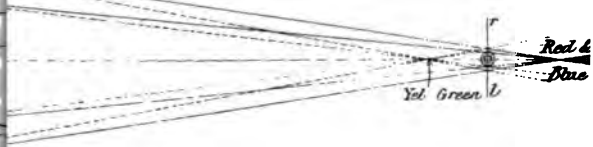


FIG. 8.



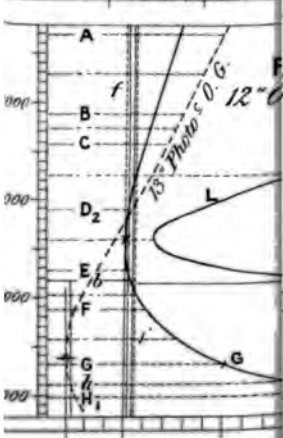


FIG. 9.

In fig. 1, as in all the other colour curves which I give, the wave-lengths are set off in arithmetical order along the perpendicular on the left hand; that is, the wave-lengths (expressed in thousandths of a millimetre) are measured by the ordinates. A scale, divided to inches and tenths, is set off along the base-line; that is, the variations in focal length for the rays of various wave-lengths are measured by the abscissæ.

Now, it seems to be a fact that large refractors are rather over-corrected compared to smaller ones. Otherwise they would show an aggressive amount of secondary red. We want a colour curve more truly representative of medium-sized refractors of average colour correction. Smaller objectives are generally calculated to refract the rays C and F to the same focus, but in practice I have good reasons for believing that the average state of correction may be said to be one in which the ray half way between B and C is united with F. The best state of correction is largely a matter of taste or individual eyesight; nevertheless, I have assumed the latter state of correction as the best to form the basis of a series of calculations, whereby the colour curve shown in fig. 2 has been arrived at. The Lick measurements are too few and too far apart to enable one to draw in the colour curve with a sufficient degree of reliability from one end of the spectrum to the other. Therefore I calculated out the colour curve (fig. 2) for a 2-foot object-glass of 30 feet focal length. The data on which I have proceeded are as follows:—

1. The very careful series of measurements of Refractive Indices for Ordinary Crown Glass and Ordinary Dense Flint Glass, executed by Dr. Hopkinson, and published in the *Proceedings of the Royal Society*, 1877 ("Refractive Indices of Glass"). These are perhaps the most accurate and reliable measurements of this sort ever executed.

2. It is well known that the refractive index for any ray of known wave-length can be expressed in terms of that wave-length with reasonable accuracy by means of Cauchy's formula—

$$\mu = a + b\frac{1}{\lambda^2} + c\frac{1}{\lambda^4} + d\frac{1}{\lambda^6} + \&c.,$$

where μ = the refractive index, λ = the wave-length, and a, b, c, and d, &c., are constants depending upon the physical properties of the particular glass in question. As Dr. Hopkinson points out, if we wish to calculate μ from λ with as great a degree of accuracy as may be obtained by actual observation, then it is necessary to work by the formula extended to four terms, as shown above. This I have done—first working out the values of a, b, c, and d for crown glass and flint glass respectively from the observed refractive indices for the four spectral lines as follows:—

TABLE II.

Ray.	Wave-length λ.	Ray.	Wave-length λ.
B	·6867	F	·4861
D_2	·5889	H_1	·3968

Next, I calculated the necessary values of $\frac{1}{\rho_1}$ for the crown lens and $\frac{1}{\rho_2}$ for the flint lens, which are necessary for refracting the ray half way between B and C (wave-lengths = ·6715) to the same focus as the ray F (λ = ·4861) at a focal distance of 30 feet. Here, as usual, $\frac{1}{\rho_1}$ stands for the sum of the reciprocals of the radii of the crown lens, and $\frac{1}{\rho_2}$ for the sum of the reciprocals of the radii of the flint lens. Then, if F represents the principal focal length of the combination, we have

$$\frac{1}{F}=\frac{\mu_1-1}{\rho_1}-\frac{\mu_2-1}{\rho_2}$$

$$=\frac{c_1-1+b_1\frac{1}{\lambda^2}+c_1\frac{1}{\lambda^4}+d_1\frac{1}{\lambda^6}}{\rho_1}-\frac{a_2-1+b_2\frac{1}{\lambda^2}+c_2\frac{1}{\lambda^4}+d_2\frac{1}{\lambda^6}}{\rho_2}.$$

Let

$$A=\frac{a_1-1}{\rho_1}-\frac{a_2-1}{\rho_2};\quad B=\frac{b_1}{\rho_1}-\frac{b_2}{\rho_2}$$

$$C=\frac{c_1}{\rho_1}-\frac{c_2}{\rho_2};\text{ and } D=\frac{d_1}{\rho_1}-\frac{d_2}{\rho_2}.$$

Then

$$\frac{1}{F}=A+B\frac{1}{\lambda^2}+C\frac{1}{\lambda^4}+D\frac{1}{\lambda^6} \quad \ldots\ldots\ldots \quad (2)$$

or

$$A+B\lambda^{-2}+C\lambda^{-4}+D\lambda^{-6},$$

which is the formula expressing the reciprocal of the focal length for any ray in terms of the wave-length of that ray.

Differentiating (2) with respect to λ, it will be found that

$$d\left(\frac{1}{F}\right)=-2\lambda^{-3}(B+2C\lambda^{-2}+3D\lambda^{-4})d\lambda \quad \ldots\ldots \quad (3)$$

On equating $(B+2C\lambda^{-2}+3D\lambda^{-4})$ to o, it will be found that

$$\lambda^{-2}\text{ or }\frac{1}{\lambda^2}=\frac{-\sqrt{C^2-3BD}-C}{3D} \quad \ldots\ldots\ldots \quad (4)$$

That is, the ray whose wave-length will satisfy equation (4)

will be refracted to the minimum focal length. (The sign of the root in (4) has been assessed from actual trial.*)

I will here give Dr. Hopkinson's Refractive Indices for the Crown and Flint Glasses respectively for the four selected rays or Fraunhofer lines :—

TABLE III.

Ray.	Crown.	Flint.
B	1·513624	1·615704
D_2	1·517116	1·622411
F	1·523145	1·634748
H_1	1·532789	1·656229

From these the following constants were obtained :—

TABLE IV.

Constant.	Crown.	Constant.	Flint.
a_1	= + 1·5031566	a_2	= + 1·5973804
b_1	= + ·0053061	b_2	+ ·0086972
c_1	= − ·00021147	c_2	− ·000084923
d_1	= + ·00001742	d_2	+ ·000027465

For a focal length of 360 inches for the F ray, it will be found that

$$\frac{1}{\rho_1} = \frac{1}{74{\cdot}4292} \text{ and } \frac{1}{\rho_2} = \frac{1}{149{\cdot}318}$$

on the supposition that the ray half way between B and C ($\lambda = {\cdot}6715$) is refracted to the same focus as F.

From these data the objective constants, A, B, C, and D—see equation (2)—are found to be as follows :—

TABLE V.

A	= + ·00275948
B	= + ·000013045
C	= − ·0000022725
D	= + ·000000050085

* It is interesting to note that the use of Cauchy's dispersion formula carried to four terms (as above) only gives rise to errors in the value of μ not exceeding and generally less than ·000010 ; which error, in the case of the crown lens, would give rise to an error of only ·018 inch in a focal length of 360 inches, and an error of ·009 inch for the same error in μ in the case of the flint lens. An error of ·000010 in *observing* μ from a crown prism of 60° angle would imply an error in reading with the spectrometer equal to about three seconds of arc only. Therefore the errors likely to arise from the above application of Cauchy's formula are no greater than the errors likely to arise in taking observations of μ with the greatest care by means of the best of spectrometers.

From the above data the colour curve shown in fig. 2 was derived. The focal lengths of the rays of the spectrum A, B, C, D_2, E, *b*, F, G, *h*, and H_1, as well as six other rays of intermediate wave-lengths (where spaces seemed to require it), were calculated and gave the abscissæ of the curve. It will be noticed that its character is much the same as the actually measured curve of the Lick refractor, if we allow for the great difference of focal length. Some years ago Professor Piazzi Smyth was good enough to send to Messrs. Cooke a series of measurements of the focal lengths of rays of various colours executed with his great spectroscope, which consisted of a large diffraction grating, a collimating telescope of 4 in. aperture and 36 in. focal length, and an observing telescope of 4 in. aperture and 68 in. focal length. Allowing for there being two objectives in use, one being nearly twice as powerful as the other, and the nature of the colour correction, which brought the D and the G rays to the same focus, the colour aberrations as measured by him (if we allow for the difficulty of attaining great exactness) were found to be on a scale proportionate to the focal powers concerned. The colour aberrations of the 27 in. Vienna telescope have also been measured by Professor Vogel and found to be substantially of the same character as those of the Lick refractor, only less in amount in proportion to the smaller focal length. So far, then, calculation and actual observation are substantially in agreement.

We have now to consider an aspect of the question which is of very great practical importance, and also extremely interesting. Large refractors are looked upon as valuable because (1) of their supposed great light-grasping or space-penetrating power, and (2) because of their greater separating or dividing power, which enables them to deal easily with very difficult double, binary, and multiple star systems which are totally inaccessible to smaller instruments. Their greater separating or dividing power upon close double stars, &c., is of course fully proved, and is well known to increase directly as the aperture; it is chiefly the light-grasping power of refractors with which I intend to deal.

First of all, I will point out what seems to me to be a most inexplicable fact (?). It has been asserted with regard to the Lick refractor (in Table I.) that the eye does *not* select a focus at that point of the optic axis where the greatest concentration of light occurs, viz. at the *minimum* focus. That the eye is able to select any distinct focus whatever out of all the innumerable various coloured foci which are continuously distributed over several inches of length in the case of very large refractors is in itself a surprising fact. But there is found to be no ambiguity in practice about the exact whereabouts of the *visual* focus of large refractors. It is asserted by Mr. Keeler that the eye places the visual focal plane at a distance of

·27 inch, or about a quarter of an inch *behind* the position of minimum focus.

In fig. 1, f_1--f_1 is the visual focal plane as placed by Mr. Keeler. It is seen to cut the colour curve in two places—in the red near C, and in the bluish green between E and F. These two colours, being about complementary, together would form an apparently *white* focus. In fact the quality of *whiteness* and *not* luminosity would seem to be the eye's main requirement, if this visual focal plane is rightly placed. Now, when an optician designs an object-glass for visual purposes, he reasons thus: This objective has to yield an image which shall appeal as much as possible to our sense of vision; therefore it is of the utmost importance that those rays of the spectrum which exert the greatest effect upon vision should be refracted to the most compact focus possible; which amounts to this, that the visually most active rays must be refracted to the *minimum* focal length, so that the brightest part of the diagrammatic colour curve may be embraced tangentially by the focal plane. He pursues this sound line of reasoning, embodies it in practice, and gets the brightest yellow-green rays condensed to the most compact focus. And then (if Mr. Keeler's estimate of the position of the visual focal plane is the true one), when he comes to actually use the telescope, his eye most persistently ignores the very focus which has been specially designed to suit it, and selects a focus of its own, *far inferior in brightness*, at quite a different position on the axis.

This seems the very height of illogical perversity. As an example of discordance between design and use it compares very well with the well-known case of the planter who supplied his black labourers with wheelbarrows to lighten their toil, and found them next day carrying them, fully loaded, *on their heads!*

Professor Harkness, in an article on the Secondary Spectrum in the "Amer. Journal of Science and Arts," 1879, September, puts forward the following ingenious method of finding the position of the visual focal plane when the amount and character of the secondary spectrum are known.

In fig. 9 is shown the same colour curve as that of fig. 2 (for a 30-foot refractor). Across this colour curve there are drawn horizontally, so as to be bisected by the colour curve, a series of short lines whose length is made proportional to the visual brightness of the light at each point of the colour scale. After the ends of these lines have been connected we have the boomerang-shaped figure shown in fig. 9. (The figure as drawn does not pretend to any accuracy.) Let this diagram be drawn on stiff paper and then cut out and balanced upon a knife-edge (which, of course, must correspond to an ordinate). Professor Harkness maintains that the position of the knife-edge necessary for a balance should indicate the position of the visual focal plane.

Now, however applicable this solution of the problem may be in the case of small objectives where the secondary colour aberrations are not too great to be embraced between the limits of the focal plane, yet it is wholly inapplicable to the case of large objectives. For the image of a star is a spurious disc, of a well-ascertained diameter, and what we are really concerned with is the quantity or luminous value of the light which actually goes to the formation of that star disc. For, as I shall presently show, the light of certain other vagabond colours focusses at points so far beyond (if not short of) the visual focal plane as to form penumbræ or circles of aberration on the latter, which are so very much larger than the star disc that the light forming these said penumbræ is diluted tens of times, hundreds of times, and even thousands of times, according to the colour. Therefore, such light certainly does *not* sensibly contribute to the brightness of the star disc, and Professor Harkness's method is no longer applicable, unless applied *only* to that brightest part of the curve which can be comprised between the limits of the focal layer; a term which I shall now proceed to explain.

It is of the very greatest importance in this inquiry to know what are the limits between which the image of a point of light or a star may be said to be approximately in *focus* in the case of well-figured objectives. Fig. 5 embodies the generally, and I believe universally, accepted idea of the longitudinal section of the cone of rays from an objective or mirror converging to form a spurious disc at D, and then diverging again in a similar manner on the other side. It is supposed as a deduction from geometrical optics that the figure is that of two similar cones on a common axis, with their points overlapping by a distance equal to $\frac{F}{A}$ times the diameter D of the spurious disc. Here F represents the focal length, and A the aperture of the O.G. In fig. 5 I have represented the average case of the focal length being fifteen times the aperture. Let it be supposed that the star disc is viewed through an eye-piece powerful enough to magnify the spurious disc to a very appreciable size, as in the case of ordinary double-star work. Then, if fig. 5 is true to fact, it is evident that if the eye-piece is pushed within or beyond focus by an amount equal to the diameter of the spurious disc multiplied by $\frac{F}{A}$, or shortly $D\frac{F}{A}$, then it will focus upon a section of the cone of rays whose diameter d is equal to $2D$, and if pushed in or out by the amount $2D\frac{F}{A}$, then it will focus upon a section of the cone of rays where $d = 3D$, and so on.

Now in the case of any objective where $\frac{F}{A} = 15$, it is well

known that the spurious disc is about ·0004 inch in diameter (or rather less). Therefore, according to fig. 5, if the eye-piece were pushed in or out of focus by a distance equal to ·0004 × 15, or ·006 in., then the appearance should be a penumbra of light equal in diameter to *twice* that of the spurious disc. Now it happened to occur to me that I would determine the limits of good focus not only theoretically, by application of the usually accepted rule, but I would also confirm it by experiment. What, then, was my surprise when I found that, so far from there being any agreement between the tacitly accepted theory and actual fact, I actually had to push in the eye-piece or draw it out in order to expand the spurious disc into a penumbra of twice its size (see fig. 5*a* and *b*), by an amount equal to ·03 inch on *each* side of focus, or *five* times as much as I had theoretically expected, while I could push the eye-piece in or out by ·015, or nearly ·02 inch, without sensibly increasing the size or destroying the character of the spurious disc. This astonished me, and led me to make a series of experiments with different eye-pieces, apertures, and focal lengths, and varying relations between apertures and focal lengths. The results turned out to be independent of the focal lengths of the objective and the power of the eye-piece, provided the magnifying power was sufficient to show the star disc. Focal lengths of 9 inches (in which case the secondary spectrum is practically nothing) up to 11 feet were tried, with the results shown in Table VI. The first column gives the relation $\frac{F}{A}$; the second gives the whole distance of travel of the eye-piece between the point where $d = 2D$ on one side of focus and the point where $d = 2D$ on the opposite side of focus. Of course D increases as $\frac{F}{A}$, and theoretically the taper or angle of the cone of rays also varies inversely as $\frac{F}{A}$, so the *theoretical* distances of travel, including that on both sides of focus (for producing the condition $d = 2D$) given in the third column, are calculated as varying as $\left(\frac{F}{A}\right)^2$. The fourth column gives the ratio of actual to theoretical distances.

TABLE VI.

$\frac{F}{A}$	Actual.	Theoretical.	Ratios.
8·4	·02 less	·004	5+
15	·06	·012	5
30	·18	·048	3·75
60	·54 about	·192	2·8

These measurements do not admit of great accuracy; but so far

as they go they clearly prove that the taper of the cone of rays becomes much more gradual as the focus is approached, or as the diameter of the cone grows small in comparison with the wave-length.

Any observer can verify these results for himself on his own telescope. The discrepancy between calculation and fact is far too great to be explained away, and the conclusion is that fig. 6 pretty accurately represents the longitudinal section of the cone of rays near the focus when $\frac{F}{A} = 15$. Figs. 7*a* and 7*b* show the differences between the theoretical and actual cones for a *large* relative aperture. I can scarcely suppose that I am the only observer who has noted this curious law, but I am not aware that the modification of the taper of a cone of rays near its focal point has ever been studied as a deduction from the undulatory theory of light.* But here we have a fact which renders possible what before seemed impossible, viz., the production of a tolerably definite focus out of the confusion of many foci; for since the bundle of rays is nearly cylindrical for a distance of nearly ·02 on each side of focus (when $\frac{F}{A} = 15$), evidently colour aberrations to that amount on each side of focus will not give rise to loss of light owing to any part of it falling outside the limits of the star disc. In all the colour curves shown in figs. 1, 2, 3, and 4 I have drawn what I call the focal layer, $f - -f$, of a width in accordance with the above experiments. The focal *plane* may be indicated by a line drawn down the centre of the focal layer, while the outer dotted lines mark the limits of the focal layer. Supposing an eye-piece is focussed upon the focal plane, then the two rays of other wave-length which focus respectively upon the inner limit and the outer limit of the focal layer will produce upon the focal plane two penumbræ of light whose diameters are equal to twice the diameter of the focussed disc (see figs. 5*a* and 5*b*); that is, about *one-quarter* of the light which focusses upon the two limits of the focal layer will fall within, and contribute to, the brightness of the spurious disc. Any light focussing sensibly beyond the outer limit or sensibly within the inner limit of the focal layer will contribute a still less fraction of its illuminating power to the spurious disc or star image.

* It can be shown that no amount of residual spherical aberration can possibly account for this apparent drawing out of the cone of rays. In order to guard myself from being misled by the well-known variability of the focus of the eye of an observer, I made use of very high power eye-pieces for the greater number of the above experiments. The most powerful eye-piece used had an equivalent focal length of ·15 inch, and in this case the utmost error in reading that could arise from the extremes of focal adjustment likely to take place involuntarily in my eye would not amount to more than $\frac{1}{333}$th of an inch. For the reasons indicated above, the use of eye-pieces of equivalent focal lengths greater than about $\frac{1}{2}$ inch would be likely to give rise to very large absolute errors in the readings.

On careful consideration it will be conceded, I think, that the thickness of the focal layer, when defined as that thickness necessary for the condition that a ray focussing upon one of the limiting planes shall produce a penumbra upon the *focal plane* of a diameter equal to twice that of the star disc, errs if anything on the side of liberality; for the integrated values of the very small fractions of the light contributed to the star disc from the colours (if any) focussing at various distances outside limits of the focal layer can scarcely be supposed to balance the loss (rising upwards to 75 per cent.) of light incurred by the star disc as regards those colours which focus at points just *inside* the limits of the focal layer, and yet just outside the limits of sharp focus, or between the outer dotted and the inner solid lines in the diagrams. Hence the luminous value of the light of that range of wave-length $\Delta\lambda$ which is embraced between the limits of the focal layer may be taken as a fair and very liberal measure of the light-grasping power of the objective when used for star work.

Although the observations recorded in Table VI. do not admit of great exactness, especially when $\frac{F}{A}$ becomes great, yet they seemed to me reliable enough to prove that the thickness of the visual focal layer does not vary as $\left(\frac{F}{A}\right)^2$, but varies roughly as $\left(\frac{F}{A}\right)^{1\cdot6}$, since doubling the ratio $\frac{F}{A}$ was found to be about *treble* the thickness of the focal layer (or rather more than that). Turning again to fig. 1, it will be seen that I have indicated one focal layer f_1 - - f_1 just where the published measurements of the Lick refractor state it to be situated, its centre or the focal plane being at ·27 inch *behind* the minimum focus. Now the curve L - - L - - L in fig. 1 (as in figs. 2, 3, and 4) is the curve of luminous intensity for the normal solar spectrum, the wave-length scale being exactly the same as that at the left-hand end of each diagram. For this luminosity curve I am indebted to the very valuable researches and experiments of Captain Abney and Major-General Festing, as published in the Bakerian Lecture for 1886.*

Since Fraunhofer's first attempt to measure the relative luminous values of the various colours of the solar spectrum, several systematic photometric investigations with the same object have been entered upon, especially those of Vierordt in 1869; but I venture to think there are no photometric measurements of the relative luminous values of the coloured constituents of white light which can be more safely relied upon than those embodied in the luminosity curves L - L - L here

* "Colour Photometry," *Phil. Trans.* Part ii., 1886.

presented. Captain Abney and Major-General Festing found their own eyes to be very fairly typical of the average results obtained by them when testing the colour-sensitiveness of other persons experimented upon.

They also well established the law that the visual photometric value of any mixture of colours is always equal to the simple sum of the separate visual photometric values of the separate coloured constituents, *whether the constituents are complementary or not*, and this supplies additional reason for doubting the existence of the supposed visual focal layer $f_1 - - f_1$ (fig. 1) in the case of the Lick refractor.

I should remark that Captain Abney's luminosity curve is the curve for the *prismatic* spectrum, and gives the maximum intensity about wave-length ·576 (citron yellow). On converting Captain Abney's curve into the curve for the *normal* spectrum with great care, I obtained the curve L - L - L with the maximum intensity transferred to wave-length ·565, citron green in colour. It will be noticed that the Lick refractor is very exactly corrected to refract this most luminous colour to minimum focus.

Now in fig. 1 the outer limits of the focal layer $f_1 - - f_1$ (placed in accordance with Mr. James Keeler's estimate of the position of the visual focal plane) cut the colour curve at two points near C in the red, and at two points near F in the greenish blue. If four horizontal lines are drawn through these points right across the luminosity curve L - L - L, then we get the two approximately rectangular strips $l - - l$ and $l_1 - - l_1$, and obviously the amount of light embraced by the focal layer will bear the same ratio to the whole light passed by the objective as the ratio which the combined area of the two strips $l - - l$ and $l_1 - - l_1$ bears to the whole area of the luminosity curve L - L - L. Hence it can be seen at a glance that if the visual focal layer is really placed by the eye at $f_1 - - f_1$, then the amount of light concentrated in the star image must be only about one-*tenth part*, at most, of the whole light transmitted by the objective! This is far too improbable to be true, and therefore, as well as for other reasons already partly stated, I feel very sceptical about the position of the visual focal plane of the Lick refractor being at $f_1 - - f_1$, as it has been stated to be. Let it be supposed, on the other hand, that the focal layer is really situated at $f - - f$, nearly tangential to the colour curve. Then, on drawing horizontal lines from the two points where the colour curve is intersected by the outer limit of the focal layer, across the luminosity curve, we get a strip which, besides being very much broader, also includes the very brightest part of the spectrum; and it can be seen from a glance at the diagram that the luminous value of the light concentrated into the star image will be at least one-half of the value of the whole light transmitted.

Thus theory most certainly demands that the visual focal plane shall be so placed as to be nearly tangential to the bend of the colour curve.

It so happens that ordinary bright green glass, if of sufficient thickness, only transmits green light, whose maximum intensity is about wave-length 5400, very close to the point of minimum focal length for ordinary objectives. Any observer possessing a large refractor of at least 8 inches' aperture will find, as I have done, that if the focus is most carefully adjusted with a high power on a white star, and then the image is viewed through the green glass and a careful readjustment of focus made, that the eye places the focal plane for the unimpeded white light at about ·02 inch only behind the green or minimum focus. I have also tried this method in the following case.

A 12·5-inch objective of 15 feet 5 inches focal length was arranged to be its own collimator; that is, it was placed close to, and with its optic axis perpendicular to, a plane optically-worked mirror. A small speculum metal bulb was placed in the eye end, just a little to one side of the principal focal point, which bulb produced an artificial star by reflecting the light from a very small electric lamp placed at one side. The light from this star diverged to the objective, passed out parallel, was reflected back by the mirror, and again converged by the objective towards a focus situated in the eye end close to the original star. This image, formed after two passages through the objective, could then be examined by ordinary eye-pieces. Now it scarcely needs explaining that, provided the speculum bulb is kept at an *unvarying* distance from the objective, then the colour aberrations (as well as any other faults in the objective) will be just *double* the colour aberrations of the same objective used in the ordinary way. So that by this method I practically had to deal with the secondary spectrum of a 25-inch objective of 30 feet 10 inches focal length, and its colour curve would be the same practically as that of fig. 2.

A knife-edge placed parallel to the focal plane, but worked backwards and forwards towards or from the objective by a micrometer screw of 100 threads per inch, was used for finding the exact positions of foci, which could be done with no greater liability to error than about ·007 in. if the mean of several trials was taken. By this Foucault method I found that the focal plane, when the green glass was used, was about ·02 in. within the focal plane selected by the eye when the white image was viewed without any coloured glass. About the same result was obtained when using the ordinary eye-piece method with and without the green glass.

These results seem to agree very well with what theory would indicate, and therefore I feel justified in placing the focal planes where I have done in all the diagrams. (I have placed

them a trifle (·01) too much towards the right in figs. 2, 3, and 4, but I have compensated for this by drawing the dotted lines going across to the luminosity curves from the proper points on the colour curves.)

Sir George Stokes some years ago devised a very simple and yet efficacious method of showing up in rather a surprising way the presence of the secondary spectrum in any objective. Fig. 8 serves to explain the principle of this test. An objective, $a - a$, is focussed very carefully upon a vertical white line drawn on a black ground. At the focus a small circle is shown, which serves as a cross-section, as it were, of the focussed line of light, which is, of course, supposed to be perpendicular to the plane of the paper. An opaque screen with its edge straight (and perpendicular to the paper) is now placed in front of the objective at $s - s$ so as to practically reduce its aperture to a semicircle. A little consideration will now show that any edge-rays focussing short of the previously-found focal plane will now strike the focal plane on the right-hand side, r, of the image, and that any edge-rays focussing beyond the same plane will strike the latter at the left-hand side, l, of the image.

It is found, in fact, that the right side, r, is conspicuously margined with yellow or citron green, and the left side, l, with reddish purple shading off into blue. Doubtless, the reason why this stray light is not noticed when the full aperture is in use is because in that case we get a combination of yellow-green *and* purple on each side of the image, and these colours, being roughly complementary (excepting perhaps in the case of very large objectives), form a greyish halo on each side, which naturally does not obtrude itself upon the attention so forcibly as the unsymmetrical combination of a citron-green halo on one side contrasted with a purplish and blue halo on the other.

Even if this test is applied to a 2-inch objective, these secondary colours may be easily detected. A black line seen against a white ground, such as the rod of a distant weather-cock, will answer equally well as a test object.

The above appearances, as exhibited by achromatics with the average degree of colour correction, clearly prove that the focal *plane* is not quite at the minimum focus, but are quite consistent with the position of the focal plane as I have shown it in the diagrams, where the inner *limit* of the focal layer is placed about tangential. If the visual focal plane were placed still further back, we should expect to see, under Sir George Stokes's test, a much greater amount of secondary green (as well as orange and bluish-green) in the case of large objectives than is actually seen. But the application of this test to an 8-inch objective did not seem to me to yield much more secondary green than the same test applied to a $3\frac{1}{2}$-inch. Thus the visual focal layer seems to cling to the minimum focus, and if in the case of very

large telescopes it should really be proved to be placed further back by normal eyes, as at $f_1 - - f_1$ in fig. 1, then our present theories of visual luminosities would have to be very radically overhauled in order to harmonise theory with fact, and to show *why* the eye should prefer in such an overwhelming degree the focus at $f_1 - f_1$ instead of the concentrated focus at $f - - f$.

Table VII. gives roughly the estimated loss of light, represented by the *shaded* portion of the luminosity curves, incurred by objectives of the sizes named through the presence of the secondary spectrum.

TABLE VII.

Luminous value of whole light transmitted in each case	= 100
36 in. Lick refractor 57 feet, F. L., loss	= 27
24 in. refractor 30 feet, F. L., loss	= 42
12 in. „ 15 „ F. L., „	= 21
6 in. „ 7·6 „ F. L., „	= 9
28 in. Greenwich refractor 28 feet, F. L., loss = about 50.*	

Thus the Lick refractor has a great advantage owing to its relatively great focal length.

(1) If the aperture of a large objective of, say, 15 in. aperture is doubled while the focal length remains the same, it is evident that the colour curve remains the same while the light distributed along it is quadrupled in intensity at every point; but the focal layer is reduced to about $\frac{1}{3}$rd, and, therefore, the range of wave-length $\Delta\lambda$ embraced by the smaller focal layer is reduced, but not reduced to quite so little as $\frac{1}{3}$rd (to know exactly to what fraction would require a very precise knowledge of the colour curve near its minimum), but roughly to about one-half, and this half includes rather more than half the light, and the result comes out that doubling the aperture of large objectives while keeping the focal length constant does not quadruple the light-gathering power for star work, but only a little more than doubles it.

(2) If both aperture and focal length are simultaneously doubled, then it is evident that the abscissæ of the colour curve will be doubled, while the focal layer will remain of the same thickness; and it will now be found that the range of wave-length $\Delta\lambda$ embraced by the focal layer will be reduced to about $\frac{2}{3}$rds; but the light in this portion of the curve is quadrupled in intensity, and the part actually embraced is of higher luminous value, and therefore the light-gathering power may be expressed as a little more than $\frac{2}{3}$rds of 4, or, say, about 3. Thus doubling all

* For some kinds of astronomical work a relatively short focal length is highly desirable, but the above figures indicate that such a condition cannot be obtained without some sacrifice of that light-grasping power which should be appropriate to the aperture.

of the dimensions of the telescope will only increase the light-gathering power about three times instead of four times.

(3) If the aperture of a large objective is kept the same while the focal length is doubled, it is evident that the abscissæ of the colour curve are all doubled; but the thickness of the focal layer being about trebled, it will be found to embrace considerably more than the former range of wave-length $\Delta\lambda$, and the light-gathering power for star work will be accordingly increased (roughly, nearly $1\frac{1}{2}$ times) *

But it may be asked, Does not the light which *accurately* focusses in the star disc become quadrupled when the aperture is doubled as in case (1)? Certainly it does, but it should be borne in mind that, owing to the spurious disc shrinking to half its former size, light from the outer zones of the objective, which focusses a little within or beyond the disc, and which before contributed considerably to its brightness, now escapes it altogether, in that although the total light within the disc gains in one way yet it loses in another (see fig. 8).

When all the facts relating to this complicated question are taken into consideration, we can scarcely escape the conclusion that customary notions of the space-penetrating power of large refractors as compared with smaller ones need serious revision, and that all estimates of the relative magnitudes of stars based upon the customarily conceived relations between aperture and visibility are more or less misleading, especially if we take into consideration the large amount of variety in the colours of stars. For it is evident that the relative light-gathering power of the same telescope on a star in which yellow-green rays preponderate will be very much greater than its light-gathering power for a star in which blue rays or extreme red rays preponderate, since the blue-green and blue and violet rays are so hopelessly wasted, while the red rays about C and beyond are also much wasted.

Another important fact should not be overlooked. It is just in the case of small stars approaching the verge of visibility that any gain or loss of light is of the most vital importance. And there is a considerable weight of evidence to show that the relative luminous value of the blue and violet rays rises as the total illumination grows less† (Captain Abney's experiments do not, however, confirm this). Hence there is probably a greater loss of light in the case of small stars than in the case of bright ones, owing to the absence of the blue and violet, and therefore the reclaiming of the latter into the visual focus rises to greater importance in these cases.

* It would be unsafe to venture upon more accurate statements or formulæ relating to light-gathering power before this important subject has received yet further elucidation.

† *Modern Chromatics*, chap. xii., *Helmholtz's Popular Scientific Lectures*, p. 110.

Supposing it established that the visual focal plane is really situated close to the minimum focus in large telescopes, it might be urged that the images of stars should appear decidedly green or greenish yellow, and not white. This is partly the fact, at any rate in the case of small stars; but in the case of bright stars, the principle that the colours of the spectrum, and especially the brightest colours, tend to appear yellowish-white when raised to great intensity,* holds good.

The concentration of light into the star image is, of course, very great in the case of bright stars viewed through large instruments. And the fact that the halo of wasted light surrounding the star image is not more aggressive than it is is easily explained by the fact that such light is for the greater part so enormously diluted, and also by the fact that the light forming the star image has the advantage of comparatively great concentration, and stands out boldly by force of contrast. The purest white paper only reflects 50 times as much light as the deepest black paper under the same illumination; and as a matter of fact it can be shown that a photometric contrast of only twenty to one is to the eye as good as a black-and-white contrast.

It scarcely needs explaining that the effect of the secondary spectrum upon vision of objects having considerable extension, such as the planets or the Moon, is to throw a haze of light over the object; the straying colours corresponding to each point of the image are spread into a halo which overlies the images of surrounding points, and while no light can be said to be lost (in the case of the Moon), in a *luminous* sense, yet it is lost for *defining* purposes as certainly as in the case of stars. The image is a tolerably well-defined one, but having the appearance of being viewed through more or less mist. If the object shows various colours, as the belts of *Jupiter*, then the image may be likened to many coloured prints which one sees, in which the outline and details are rendered sharply in black, while the colours are sponged on anyhow; in the same way the image of *Jupiter* may be defined very well as regards outline and details by means of the most luminous green, yellow-green, and yellow rays; while the colours, such as the blue rays and the more extreme red, are spread on where required in a sort of diffused wholesale fashion. There is little to wonder at, then, in the fact that reflecting telescopes have got the reputation for defining coloured details more clearly than the larger refractors. It is the blue which is principally missing, and a number of experiments have been made which tend to show that the *colouring* power and the defining power for delicate details, of blue rays, is of a higher value than their small visual luminosity would lead us to expect.†

* *Modern Chromatics*, chap. xii.

† *Modern Chromatics*, p. 185; *Helmholtz's Popular Scientific Lectures*, p. 110.

I thought it would be of great interest to show the graphic colour curves (calculated in exactly the same way) for the 33-inch Lick Photographic Objective (about 47 feet F. L.), and also for the standard 13-inch Photographic Objective of 135 inches F. L. for charting the heavens. The focal layers are shown in both cases at the minimum bend. The large relative aperture of the 13-inch reduces the focal layer considerably. It will be seen at once that the focal layers embrace only a comparatively small portion of the range of wave-length to which the photographic plates are sensitive, and there is little doubt that the enlargement of the star images which takes place when either the stars are brighter or the exposures are increased may easily be explained by supposing that the aberrant rays begin necessarily to affect the plate at greater and greater distances from the true star disc. If this is the case, then, we should expect a marked difference between stellar photographs taken with reflectors and those taken taken with refractors. Of the former I have not sufficient information to enable me to confirm this point. If a curve of photographic sensitiveness were supplied in figs. 1 and 3 it would certainly be found that there is a considerable quantity of actinic light lost for defining purposes through the presence of the secondary spectrum, especially if we allow for the fact that the minimum part of the colour curve bends back and returns upon itself much more abruptly than in the case of the visual colour curve. This should be expected from the fact that the irrationality of dispersion between ordinary crown and dense flint glasses is greater as the blue end of the spectrum is approached.

It is abundantly evident that an objective which would refract all the colours as well as the blue actinic rays to exactly the same focus will possess more practical advantages than would appear at first sight. Hoping to introduce to this Society on another occasion an objective which will do this, and which is quite practicable up to reasonably large sizes at any rate, I must now bring to a conclusion a paper which has considerably surpassed the limits which I had at first intended for it.

Buckingham Works, York.

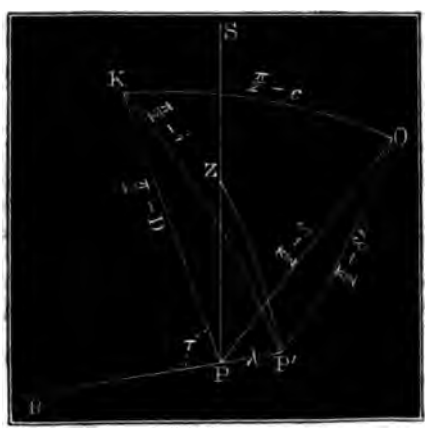
To adjust the Polar Axis of an Equatorial Telescope for Photographic Purposes. By Professor Arthur A. Rambaut, D.Sc.

An equatorial telescope intended for ordinary visual work may be considered to be adjusted with sufficient accuracy, as far as its polar axis is concerned, if the errors in altitude and azimuth do not exceed a single minute of arc. In most cases, too, the ordinary method of adjusting the axis by readings of the circles is not susceptible of higher accuracy unless elaborate precautions are taken to eliminate the effect of flexure.

When, however, a telescope is intended for photographic purposes it is advisable to orient the axis with a much higher degree of precision than this. In the *Bulletin du Comité International Permanent pour l'exécution photographique de la Carte du Ciel*, Tome 1er, p. 385, Dr. Scheiner points out a method by which this may be accomplished. It has, however, the disadvantages that the corrections have to be made tentatively during the progress of the observations, and are affected by the variations in the refraction as the star changes its position.

In the method which I propose the errors in the position of the axis are determined by measures of a photograph on which two short exposures of a star have been taken at an interval of 15 or 30 minutes, the driving-clock of the instrument being allowed to run without hand correction in the meanwhile.

If the axis is not perfectly adjusted the two images will not fall on exactly the same point of the plate, and measures of the distance between the two images when corrected for the effect of refraction will afford the material for determining the position of the axis.



I assume, for the present, that the driving-clock is running accurately to sidereal time, and that the errors of the instrument have been reduced to within a few minutes of arc.

Let P be the pole of the heavens, and PS the meridian towards the south at S; Z the zenith; P′ the pole of the instrument; K the point in which the extremity of the declination axis if produced would meet the sphere; and O the point towards which the telescope is direced.

Let the arc PP′ be denoted by λ,

" " KP′ " $\frac{\pi}{2}-i$,

" " KO " $\frac{\pi}{2}-c$,

" " KP " $\frac{\pi}{2}-D$,

" " ZP′ " ζ,

" angle SPP′ " h,

" " SPO " θ,

" " KPR " τ.

Then K describes a circle round P′ and of course PP′ is fixed. Let t_0 be the reading of the hour-circle when the point K is on the great circle PP′, and t the reading when the telescope is directed to a point O west of the meridian. Then the angle KP′P is equal to $t-t_0$. We thus obtain from the triangle KPP′

$$\sin D = \sin i \cos \lambda + \cos i \sin \lambda \cos (t-t_0),$$

and

$$\sin \tau \cos D = \cos i \sin (t-t_0),$$

or to the first order of small quantities,

$$\left.\begin{aligned} D &= i + \lambda \cos (t-t_0), \\ \text{and} \quad \tau &= t-t_0. \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad (1)$$

We see also that θ is the hour-angle of the telescope. Let us put δ equal to the true, and δ' equal to the instrumental, declination of the point O; hence δ' is constant throughout the exposures.

If now the object-glass end of the telescope makes an angle $90°-c$ with the declination axis, then $KO = 90°-c$, and we have

$$\sin c = \sin D \sin \delta + \cos D \cos \delta \cos (\tau + \theta - \tau - h),$$

or

$$\theta = D \sin \delta + \cos \delta \sin \left(\tau + h - \theta - \frac{\pi}{2}\right).$$

Hence unless the star under observation is within a few minutes of the pole

$$\sin\left(\tau+h-\theta-\frac{\pi}{2}\right)$$

is a small quantity, for which we may write simply

$$\tau+h-\theta-\frac{\pi}{2}.$$

Thus we obtain

$$\theta=\tau+h-\frac{\pi}{2}-c\sec\delta+\mathrm{D}\tan\delta;$$

or, substituting from (1), we find

$$\theta-t=-t_0+h-\frac{\pi}{2}-c\sec\delta+i\tan\delta+\lambda\tan\delta\cos(t-t_0) \quad . \quad . \quad . \quad (2)$$

whence

$$d(\theta-t)=-\lambda\tan\delta\sin(t-t_0)dt-[c\sec\delta\tan\delta+i\sec^2\delta+\lambda\sec^2\delta\cos(t-t_0)]\,d\delta.$$

Again, we have from the triangle PP′O

$$\begin{aligned}\sin\delta'&=\sin\delta\cos\lambda+\cos\delta\sin\lambda\cos(\theta-h)\\&=\sin\delta+\lambda\cos\delta\cos(\theta-h);\end{aligned}$$

but from equation (2) we have, to a first approximation,

$$\frac{\pi}{2}+\theta-h=t-t_0,$$

and therefore

$$\sin\delta'-\sin\delta=\lambda\cos\delta\sin(t-t_0),$$

from which we find, to the same degree of approximation,

$$\delta=\delta'-\lambda\sin(t-t_0),$$

and consequently

$$d\delta=-\lambda\cos(t-t_0)\,dt.$$

We thus obtain

$$\left.\begin{aligned}d(\theta-t)&=-\lambda\tan\delta\sin(t-t_0)\,dt,\\ \text{and}\qquad d\delta&=-\lambda\cos(t-t_0)\,dt.\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Again, if ϕ denotes the latitude, we have

$$\cos\zeta=\sin\phi\cos\lambda+\cos\phi\sin\lambda\cos h=\sin\phi+\lambda\cos h\,.\cos\phi.$$

Let $\zeta+k=90^\circ-\phi$, *i.e.* let the pole of the instrument be *too high* by the angle k; then

$$\cos\zeta=\sin(\phi+k)=\sin\phi+k\cos\phi,$$

and

$$\sin\zeta=\cos\phi-k\sin\phi.$$

Hence

$$k=\lambda\cos h.$$

If also we take A to be the azimuth of the point P′ measured from the *north* towards *west* we have

$$\sin A = \frac{\sin \lambda \sin h}{\sin \zeta} \text{ or } A = \lambda \sin h \,.\, \sec \phi.$$

Now, if the telescope is in the first instance pointed to a star, then $d(\theta - t)$ denotes the difference in hour-angle between the star and the telescope at the end of the interval dt, or $d(\theta - t)\cos\delta$ represents the displacement of the star's image on the plate in the direction of the parallel. Also $d\delta$ is the displacement at right angles to the parallel. Hence if we denote these displacements by X and Y respectively, we have the following equations:

$$\left.\begin{aligned} X &= d(\theta - t)\cos\delta = -\lambda \sin\delta \cos(\theta - h)\frac{15dt}{R}, \\ Y &= d\delta \qquad\qquad = \lambda \sin(\theta - h)\frac{15dt}{R} \\ &\text{(where } R = 206265), \\ k &= \lambda \cos h, \\ \text{and} \quad A &= \lambda \sin h \,.\, \sec\phi. \end{aligned}\right\} \quad \ldots \quad (4)$$

From these we obtain

$$\left.\begin{aligned} k &= -\left\{\frac{X}{\sin\delta}\cos\theta - Y\sin\theta\right\}\frac{R}{15dt}, \\ \text{and} \quad A &= -\left\{\frac{X}{\sin\delta}\sin\theta + Y\cos\theta\right\}\frac{R}{15dt}\,.\sec\phi, \end{aligned}\right\} \quad \ldots \quad (5)$$

in which θ is the hour-angle of the star at the middle of the interval between the exposures.

With regard to the signs of the quantities k, A, X, and Y we see

(α) That k is the angle through which the pole of the instrument must be *lowered*.

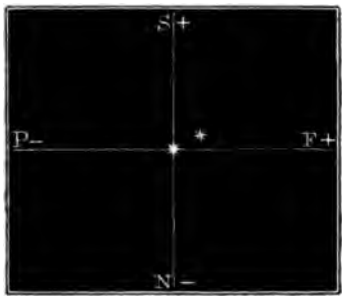
(β) That A is the angle through which the *northern* end of the mounting must be turned towards the *east*.

(γ) From the first of equations (4) we find that X is positive when $d\theta > dt$, i.e. when the instrument moves faster than the star. Hence the second image will fall to the *following* side of the first, or the *following* is the *positive* direction of X.

(δ) From the second of equations (4) we see likewise that Y is positive when $d\delta$ is positive, or when the telescope at the end of the exposure is directed to a more northern point than at the beginning; consequently the second image will be *south* of the first.

Hence we see that taking as axes of X and Y, the projections of the parallel and meridian through the first image, and the plate being placed so that the stars on it appear as seen in an inverting telescope, the positive and negative directions of the

axes will be disposed in the usual manner as shown in the diagram.



The Refraction:—If the star whose image we are considering is not very close to the pole, the effect of the change in the refraction during the exposure must be taken into account when the highest accuracy is desired in the adjustment of the instrument.

This correction may be applied very conveniently by means of the formulæ which I published in the *Astronomische Nachrichten*, No. 3125. In the case before us we have $d\delta$ equal to zero, and da equal to dt; and since we need only consider the terms of the first order the formulæ become

$$\Delta X' = \beta \cdot \frac{\cos\phi\,(\cos\delta\cos\phi + \sin\delta\sin\phi\cos\theta)}{\{\sin\delta\sin\phi + \cos\delta\cos\phi\cos\theta\}^2} \frac{15\,dt}{R}$$

and

$$\Delta Y' = \beta \cdot \frac{\cos\phi\sin\phi\sin\theta}{\{\sin\delta\sin\phi + \cos\delta\cos\phi\cos\theta\}^2} \frac{15\,dt}{R}.$$

If, then, X′ and Y′ are the measured displacements along and at right angles to the parallel, we have

$$X = X' + \Delta X' \qquad \text{and } Y = Y' + \Delta Y'.$$

Having thus determined k and A by means of equations (5), the corrections may very easily be effected in the following manner:—

(1) *To adjust in altitude*, point the telescope to a star near the meridian and not very far from the pole. Set the star on the horizontal wire, and by means of the scale ordinarily found at the eye-end of the pilot or guiding telescope, displace the wire in declination through an angle equal to k. Using the adjusting screws at the base, bring the wire once more into coincidence with the star. The axis will then be correctly adjusted in altitude.

(2) *To adjust in azimuth*, point the telescope on a star near the meridian and not far from the equator. Having set the star on the vertical wire, displace the latter through an angle D [=A sin $(\phi-\delta)$]. When the wire is brought once more into coincidence with the star by means of the adjusting screws at the

base of the instrument, the axis will be correctly adjusted in azimuth.

Irregularities in the Clock.—In what precedes I have supposed that the clock was running correctly to sidereal time.

In this connection there are two cases to be considered. If the clock is one of Sir Howard Grubb's latest pattern, in which the rate is electrically controlled by a sidereal pendulum clock, this condition will be fulfilled.

If, however, the clock is one whose rate may be depended upon to remain constant during the exposure, but without control from a pendulum clock, it may be rated to keep sidereal time by observation of a star at the equator. For the first of equations (3) shows that $d(\theta - t)$ is zero for such a star. Hence, in order to rate the clock correctly, it is only necessary to direct the telescope to a star on the equator and to adjust its rate until it keeps pace with the star.

But if the rate cannot be depended on to remain constant during the interval between the exposures, since the principle of the method will not allow of any hand correction being introduced, it will be necessary to reject the displacement in R.A. and to depend entirely on that in declination. We can, however, by properly selecting the stars, obtain both k and A from these displacements. For if in the first instance we take a star on the meridian, since θ is then equal to zero, we find from equation (5) that

$$A = -\frac{YR}{15\dot{d}t} \sec \phi;$$

and if we next take a star at a distance of 6^h from the meridian, we have

$$k = \frac{YR}{15\dot{d}t}.$$

The Observatory, Dunsink, Co. Dublin:
1893 *December* 1.

Note on a Star-correction Facilitator, or an instrument for readily obtaining the products of pairs of numbers, one number being taken from one set (e.g. *day-constants*) *and the second from another set* (e.g. *star-constants*). By T. C. Hudson, B.A. (Cantab.)

(*Communicated by A. M. W. Downing.*)

This instrument, which may for the present be briefly described as an antilog.-roller with a set of four shiftable windowed sheaths, was primarily devised for the sake of minimising the labour involved in the calculation of star ephemerides. The principle may be explained as follows:—

I. If the first 100 natural numbers be written at regular intervals, thus,

0	10	. . . .	90
1	11	. . . .	91
2	12	. . . .	92
.	.		.
.	.		.
.	.		.
.	.		.
9	19	. . . .	99.

and if a pair of compasses be stretched from one number to another, and bodily moved about on the paper, up or down, right or left, but without altering the direction of the join of the points, then the *difference* of the numbers under the points will evidently remain the same whatever the numbers may be.

II. If these 100 natural numbers be replaced by the antilogarithms of ·00, ·01, ·02, . . . ·99, then the *ratio* of the quantities under the compasses will remain constant. This is evident from the fact that if the difference of two quantities be constant, so also is the ratio of their antilogarithms.

These considerations led to the construction of the instrument, which may be thus described.

On a cylinder are printed, or otherwise exhibited, at regular intervals, 100 columns of numbers, viz. the four-figure antilogs. of

·0000	·0100	&c.	·9900
·0001	·0101	&c.	·9901
·0002	·0102	&c.	·9902
. .	. .		. .
. .	. .		. .
. .	. .		. .
·0099	·0199	&c.	·9999
·0100	·0200	&c.	·0000
. .	. .		. .
. .	. .		. .
. .	. .		. .
. .	. .		. .
·0199	·0299	&c.	·0099
·0200	·0300	&c.	·0100

the last column having, of course, the first for its right-hand neighbour. Thus the cylinder practically furnishes a complete antilog. table, rolled end to end, and combined with a similar

table placed beneath it and rotated one space to the left. The arguments ·00, ·01, . . . ·99 are written above the top row, and ·02, ·03, . . . ·99, ·00, ·01 below the bottom row. The vertical arguments may conveniently be written on a slip of card and applied to the cylinder when necessary.

On this cylinder is fitted a cylindrical sheath, capable of sliding up and down and of slipping round the cylinder. The length of the sheath is only 100 spaces, that is, half the length of the cylinder. This sheath is moved up to the top of the cylinder, so as to cover the upper half, and a zero mark is made over the antilog. of ·0000. Then thirty-eight windows are cut in the sheath so as to disclose the thirty-eight day-numbers called *A*, or, more precisely, so as to disclose the thirty-eight antilogarithms of the logarithmic day-constants known as log *A*. Finally, arrows are drawn from window to window showing the order of succession. Three other sheaths are made in like manner for the sets *B*, *C*, and *D*.

In order, then, to obtain the thirty-eight quantities called *cC* for a star whose log *c* is, say, 9·2764, we have merely to shift the "*C*" sheath till its zero mark is in column 27 and row 64, whereupon the thirty-eight windows immediately disclose the thirty-eight required quantities *cC* ready to be transcribed without either addition, interpolation, or the eye-wearying process of *selecting* the right number from the rows and columns of a large table. The number strikes the eye, without requiring to be selected from its neighbours.

The *decimal significance* of the antilogarithms is, of course, not given by the cylinder, just as an ordinary antilogarithm table does not furnish us with the position of the decimal point. But the value of the first quantity may be easily ascertained, and then the decimal significance of the rest of the numbers may be determined by keeping an eye on the differences, and by the consideration that the ratio of any two *cC*'s is the same for all stars.

Photograph of the Nebula H I 168 *Ursæ Majoris.*

By Isaac Roberts, D.Sc., F.R.S.

The nebula is in R.A. $10^h\ 12^m$, Decl., 41°·57′ north, and the photograph was taken on 1893 April 14, with an exposure of the plate during 4 hours. The scale of the enlarged photograph now presented is 1 millimetre to 24 seconds of arc.

The nebula is No. 3,184 in the *New General Catalogue*, and 2,052–2,053 in the *General Catalogue*.

Sir J. Herschel, in the *General Catalogue*, p. 83, describes 2,052 as pretty bright, very large, round, very gradually brighter

in the middle; and 2,053 as pretty faint, very large, round, very gradually brighter in the middle.

Lord Rosse (*Phil. Trans.* 1861, pl. 27, fig. 13, and *Observations of Nebulæ and Clusters of Stars*, p. 82) states that the *preceding* part is probably a portion of a ring. "The nebulosity connecting the three principal knots is very, very faint, but I have no doubt of its existence. The faint branch *following* the bright nebulosity is more doubtful."

The photograph shows this to be a very interesting spiral nebula, almost perfect in outline. In the centre of the spiral is a star of 14th to 15th magnitude, and around it are formed the convolutions, each of which is broken up into stars; four of them (omitting the bright star on the north side) are sharply defined, and the others, which are numerous, appear to be in all stages of development between very faint star-like patches and the defined ordinary star images.

There is still nebulosity between some of the spirals, as well as between the stars in the convolutions.

Several photographs of spiral nebulæ have from time to time been presented to the Society, and each one of them shows the spirals to be broken up into stars, or into star-like condensations, and I think the cumulative evidence thus brought before us amounts to a demonstration of the formation of stars by the condensation of nebulosity, or by the aggregation of meteoric or other cosmic matter.

Photograph of the Nebula H I 205 *Ursæ Majoris.*
By Isaac Roberts, D.Sc., F.R.S.

The nebula is in R.A. $9^h\ 14^m$, Decl. north $51°{\cdot}34'$, and the photograph was taken on 1893 April 12, with an exposure of the plate during 3 hours and 30 minutes. The scale of the enlarged photograph now presented is 24 seconds of arc to 1 millimetre.

The nebula is No. 2,841 in the *New General Catalogue*, and 1,823 in the *General Catalogue*.

Sir J. Herschel, in the *General Catalogue*, p. 79, describes the nebula as very bright, large, very much extended in the direction $150°{\cdot}8'$, very suddenly much brighter in the middle; equal to a star of 10th magnitude.

Lord Rosse, in his *Observations of Nebulæ and Clusters of Stars*, p. 75, states that it is like the nebula in *Andromeda*, with the nucleus a little nearer the *following* edge than the centre. I "think there is a small part of detached nebulosity which seems to have a connection with the other," and he gives a rough marginal sketch.

The enlarged photograph, and more clearly the negative,

show the nebula to be a symmetrical ellipse, with a distinctly stellar nucleus in the midst of dense nebulosity which surrounds it. Outside this is a well-defined zone of faint nebulosity, and then a broad ring, or zone, with little if any nebulosity in it. Outside this, again, is a very dense broad ring of nebulosity, and a patch of very faint nebulosity extends beyond the ring at the *s.f.* end.

The nebula is probably a circular or oval system seen in perspective elongated, and there are indications of condensations of matter of the rings.

The nebula resembles, on a very small scale, the great nebula in *Andromeda*, and the description given by Lord Rosse agrees well with the photograph, though he could not have seen the details which are there shown.

The Variable Spectrum of β Lyræ in the Region of F—*h*.
By the Rev. Walter Sidgreaves, S.J.

In the August number of *Astronomy and Astro-Physics* Mr. Keeler has given us an interesting account of his experiences of the variations of the spectrum of *β Lyræ*. All observations of progressive or recurring changes in the starry universe, made with the great refractor at Mount Hamilton, are necessarily of the highest value; and those changes which are indicated to us by the delicate linings of a spectrum band seem to have greater claims upon the light-capacity of the great glass.

Mr. Keeler has drawn attention to the main difficulty which besets all eye observations of delicate changes, in his remark that it is necessary to preserve a faithful memory of an appearance noted perhaps many days past. Photography, here, has the advantage of presenting to the eye simultaneously both the past and the present state of things. And, for this reason, Mr. Keeler does not claim for his notes a value at all equal to the photographic impressions of the spectrum of *β Lyræ*, obtained with much smaller optical power. We think that he underrates the merit of his own work, and overrates the advantages of the photographic records. That these are considerable there can be no question. But it is not clear whether even greater allowance has to be made for the photographic plate than for the eye, under the diverse conditions of our treacherous atmosphere.

We cannot claim for the spectrographic plates of *β Lyræ* obtained at this observatory any such superiority over Mr. Keeler's notes upon his eye observations at Mount Hamilton. The star is only fairly within the working capacity of the 8-inch refractor on the clearer nights, and our recent examination of 45 plates shows that under these circumstances the

photographic plate may be more treacherous than the retina of the eye. The eye presents at least the same retina to the light rays, at all its observations; while the camera must change its plates. A little difference in the sensibility of the plate may greatly alter the value of the picture, when the light collector can barely provide sufficiency. An over-exposed plate can be dealt with fairly successfully in the process of developing; but an under-exposure can never be brought up to compare accurately with a plate that has had the advantage of the full action of light. Under-exposure has been the chief failing in the series of plates. It has not been possible to secure a full exposure on all occasions, owing to a defect in the clock movement as applied to the method of trailing. A small inequality in the thread of the driving-screw produces a periodic oscillation of a star about a mean position in the field when the clock is adjusted to true star time. And when the clock is slowed, the star travels across the field with a periodic variation of rate, and leaves on the photographic plate a spectrum band composed of a series of rulings. A slow trail, which corresponds to a long exposure, is shown on the plate by the closeness of the rulings; and the limit to the length of exposure is the rate of trail which gives an alternation between a complete halt and a march of the star's image; for if the image return upon its journey, the spectral lines must become blurred, unless the motion is more accurately parallel to the edge of the prism than can be secured without the use of a slit and constant attention to the instrument during the time of exposure. The difficulty of securing this adjustment for *β Lyræ* has been the cause of a number of failures; but the series of available plates numbers in all 45. Ten of these were taken in the spring and summer of 1892, on occasions of exceptionally clear nights, and the other 35 plates were the result of a set purpose to make as complete a collection as possible during the favourable position of the star in the last half of the present year. These were obtained between the third week of May and the middle of August, when the series came to an end with the last night of the 8-inch objective. The telescope was dismounted on August 16, in order to send its central box to Dublin to be fitted with the new tubes required for the Fr. Perry-Memorial objective. We may look for a more valuable record of the variations of the star's spectrum from the greater light power; but I have thought it well to offer the results of a very careful examination of the plates already obtained to the R.A.S. They may be confirmed or reversed by the more reliable plates of the future, but at least the comparison will show how far a weaker instrument can be trusted.

The spectrograph and its adjustments have been already described in the *Memoirs*, vol. li. p. 30. No alteration has been made in the instrument since its employment upon the

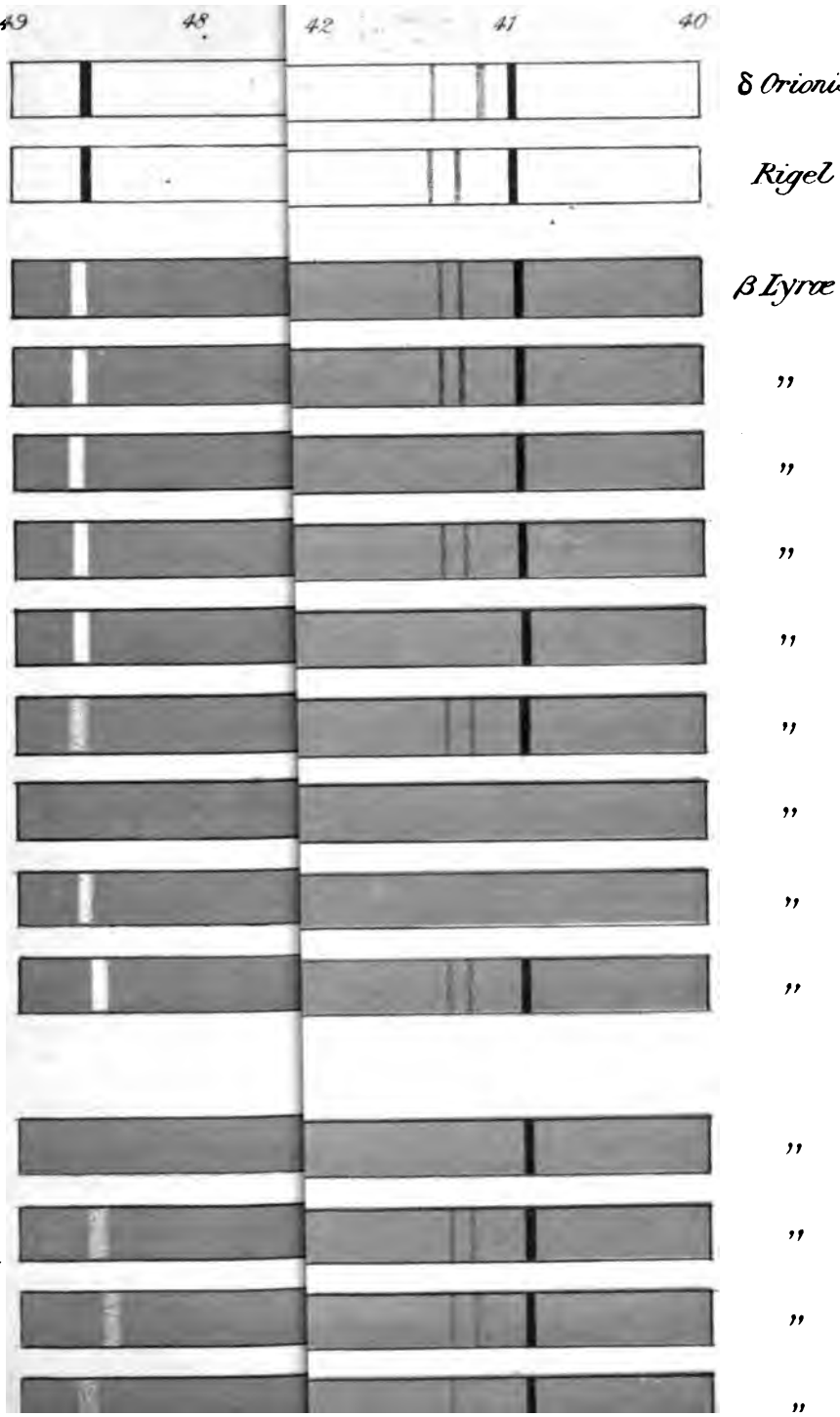
Nova of last year. The plates of *β Lyræ* have been arranged according to the day-age of its light variation, reckoned always from the preceding principal minimum.

In the accompanying map (Plate 2) the spectrum is given for each day-age, except day 10, for which there is no photograph, but only the more prominent lines have been marked. There are on some of the plates many more lines and bands which undoubtedly go through considerable changes. These have been omitted as not being sufficiently within the optical power of the instrument.

The wave-lengths are quoted from the curve constructed for the *Nova* of last year. They are referred to the position of G′ at the marginal separation of its bright and dark representatives on the first days of the variation period, and the red side edge of the absorption line has been retained for the fiducial position for all plates not showing the red side radiation. The red side edge of F has also been employed as a second or corrective fiducial point on those plates which showed it with sufficient certainty. On some of the plates it was doubtful whether the line was F or a stranger, and on these plates it was not employed as a reference position.

It seems probable, from our examination of the plates, that the star's spectrum varies in general with its light period; for whenever there are more photographs than one for the same day-age, the same spectrum on the whole is shown on all the plates, making proper allowance for more and for less successful exposures. But there are exceptions which may eventually be brought into better harmony with some other period than that of the light curve. The most notable of these is shown in the map for the 11th day, which will be referred to again in our remarks upon the separate lines; and there may be others, if our estimation of the relative value of the photographs is much in error. But the terms maximum and minimum, as applied to prominence or strength of the radiation lines, do not appear to run with the corresponding epochs of the light curve. The maximum display of bright lines is between the 1st and 2nd day after the principal minimum, and the changes appear to be quite abrupt; for on the 11th and 12th days the bright lines are quite weak on good plates, and on the 13th day, a few hours before the principal minimum, the spectrum is still without bright lines.

Of the individual lines shown in the map, F is probably the one we should say least about, for the sensibility of the plates employed upon the star falls off rapidly at this region of the spectrum. But the contrast between the relations of F and G′ in the spectra of *β Lyræ* and *γ Cassiopeiæ* is noteworthy; viz., that with the same instrument and the same plates, F is much stronger than G′ in *γ Cassiopeiæ*, and generally much weaker in



Spottiswoode & Co Lith. London.

IV.

β Lyræ. Its inferiority in *β Lyræ* may be a photographic deception; for it is possible that the actinic energy of the F rays may increase more rapidly with the increment of light than that of the rays of G′.

The companion lines at λ471 seem to have a variation of their own, besides the general waning to extinction shown in the map. They are very strongly marked on the two best plates belonging to day 1; but they are wholly absent from the two very good plates of day 2, while a third plate of this day-age shows them quite clearly.

The group of lines at λ447–8 is perhaps the most prominent feature in the spectrum. The stronger absorption line at the blue side fades away rapidly after the 3rd day, and the middle radiation line begins about the same time to divide, and gradually increases in the width and separation of the parts until the 11th day, when every part of the group is completely extinct on three plates belonging to this day-age, two of which are much too good to deceive. The reappearance of the absorption lines on the 12th day, without any bright companions, is also quite certain; two very good plates of this day-age bear witness to this, two ill-defined ones confirm them, and one inferior plate is doubtful.

λ438 and G′. The radiation component of line 438 dies gradually from day 1 to day 4, when it is almost if not quite dead; while the absorption retains its full strength till the same 4th day, when it suddenly collapses with its companion. On the 7th day a new order has apparently just commenced; the absorption line has barely recovered, but the radiation has passed from its red to its blue side, and the same change has simultaneously commenced in the pair at G′. Both the components of G′ have slowly lost their strength during the 4th, 5th, and 6th days; a more rapid decline has set in after day 6, and on day 7 the dark and bright companions appear faintly in the reversed order. The radiation is now on the blue side of the absorption. The absorption is narrow, and the radiation broad and undefined. Both are exceedingly weak, but are not doubted. On the 8th day the new order of the lines is quite manifest, and on the 9th they have attained apparently their maximum intensity, with the absorption quite equal to those of the first days, and the radiation about the same as on the 5th day. The same order is retained until the 12th day, the radiation fading slowly to nothing on this day, while the absorption remains unaltered till the 13th day, when it has suddenly vanished.

From this it appears that the reversal of the relative positions of the bright and dark components of G′, and also probably of the weaker pair at 438, takes place at the secondary minimum, and again at the principal minimum, for the date of the 7th-day plate is ten hours after the secondary minimum, and this plate just

shows the change of position; and the date of the 13th-day plate is two hours before the principal minimum, and here both components of G are nearly completely obliterated. We have, however, the evidence of only one date for each of these day-ages—the 7th and 13th; viz., two plates for the *same* 13th day, and a single plate for the 7th day. But their evidence has recently been confirmed by a fortunate trial plate upon *β Lyræ*, with the same spectroscope mounted upon the Fr. Perry-Memorial telescope. This plate is of the same light age as the 7th-day plate of the series, having been exposed at 9 hours after the secondary minimum, and it shows the same approximate obliteration of G′ as is sketched on the 7th day of the map. Two other trial plates with the new objective confirm the succession of changes in G′ as given by the series of exposures with the old 8-inch glass. One of these fills the gap of the 10th day, and shows the spectrum of the 9th day, with a small diminution of intensity in the absorption and radiation components of G′, so far as we can judge between the different conditions of the exposures; those of the 9th day being by slower trails with less light, and that of the 10th by a quicker trail and more light. The remaining trial plate was, as soon as developed, pronounced to be a 1st- or 2nd-day plate; and was found, on reference to the *Companion to the Observatory*, to belong to the 1st day, at 11 hours after the principal minimum.

The remaining line at λ410 is at a weak part of the plate. The absorption is clearly seen on all the days except 7 and 8, and this change on the 7th day is confirmed by the stronger photograph already mentioned, which has it only as a mere ghost. No plate of the series shows the companion bright hydrogen in this region, but the stronger photograph of the 1st day by the new objective shows it clearly on the red side like its kin-fellow at G′.

In summarising our conclusions we give them as they come from our own photographs only, without reference to the conclusions drawn from observations with other and better instruments.

1°. It is quite certain that the hydrogen line at G′ is at times double, one part being bright and the other dark.

2°. It is quite certain that the bright component is sometimes on the red side and sometimes on the blue side of the absorption line.

3°. It is highly probable that this change is periodical and coincident with the two minima of the light period.

4°. It is probable that the obliteration of both components at the times of the minima is due to neutralisation by their superposition.

5°. It is uncertain whether the bright component passes

across the dark one as a stationary line, or the two exchange positions.

6°. It is probable that the bright lines are strongest during the first three days of the light period.

The periodic change in the relative position of the two components of G′ agrees very closely with the result of Professor Pickering's examination of the Harvard College photographs, as given in *A.N.* No. 3,051, and confirms his supposition of the binary nature of the star; but a rather elongated ellipse would suit the quickness of change at the minima of brightness, and the other requirements of our map, better than a circular orbit. The major axis being nearly in our line of sight, and the smaller and cooler star being between us and its primary at periastron, the continuous spectrum would be weakened by the partial eclipse; and the bright lines might be brought to their maximum intensity just after periastron by the heat developed in the tidal action upon the smaller star. They would at first be neutralised by the absorption lines while the star was crossing our line of sight, and would appear on the red side of the absorption, as soon as this rectangular inclination of the motion was sufficiently reduced. This would occur soon after the principal minimum, considering the high velocity at this part of the orbit and the short time-period of the revolution. The bright lines would retain their strength for some days, and then might cool down gradually to extinction before the next periastron. At the apastron there would be an eclipse of the smaller star, corresponding to the secondary minimum of brightness, and there would be a repetition of the superposition of the bright and dark lines, causing a temporary suppression of both, to be followed by the reversal of their relative position.

All these changes are faithfully followed by the hydrogen light at G′, and the irregular appearances of other lines are to be expected from the nature of their origin in a tidal commotion. But at the precise epoch of a secondary minimum the dark hydrogen line should be visible without its radiant companion; and if this be discovered, it will greatly strengthen our confidence in this explanation of the variations of the spectrum of *β Lyræ*.

Stonyhurst College Observatory:
1893 *December* 1.

Two New Variable Stars. By the Rev. T. E. Espin, M.A.

On August 21, while sweeping for stars with remarkable spectra, I came across a fine red star which was found to be wanting in Argelander's charts. The place obtained for it was:—

R.A. $19^h\ 7^m\ 15^s{\cdot}8$ Decl. $+25°\ 46'{\cdot}4$ (1855).

The spectrum was banded, and believed to be III. type. As I suspected it might turn out to be variable, it was watched. On September 27 it was found to have diminished a magnitude. The following are my observations of it:—

1893.	Mag.		Mag.
Aug. 21	9·0	Oct. 11	11
Sept. 7	10·0	Nov. 13	11·5
Oct. 4	10·3	Dec. 1	12·0

On August 24, while sweeping in *Cygnus*, another fine red star was detected. It was near the place of a star of Argelander's, and was one of a wide pair. Careful differentiation on September 12 gave me for its place:—

R.A. $20^h\ 46^m\ 59^s{\cdot}3$ Decl. $+\ 46°\ 47'{\cdot}2$.

It therefore is $18^s{\cdot}7$ f. DM. $+\ 46°{\cdot}3078$, mag. 9·5. In the spectroscope the two star-spectra overlap, but it is evidently banded, and appeared more like type III. than IV. As this region had been swept over in previous years and no red star noted in this place, I concluded it was probably a new variable. It was not till October 4 that any change was noted, and even then the loss of light was so small that it would not have been seen except for the neighbouring star. The following are my observations of it:—

1893.	Mag.		Mag.
Aug. 24	9·1	Nov. 13	10·8
Oct. 6	9·4	Dec. 1	11·5
Oct. 11	9·6		

Note on the Spectra of Certain Red Stars.
By the Rev. T. E. Espin, M.A.

In the summer the mirrors of the 17¼-inch were resilvered, and during the autumn the telescope has been used for re-examining the spectra of certain stars and for sweeping over the red region in *Cygnus*. I give herewith the results:—

(1) *Es. Birm* 57, R.A. $2^h\ 43^m{\cdot}3$, Decl. + 56°34′ (1900), Mag. 9·4. This is D.M. + 56°·724. This red star was found by Pickering, who suspected bands. Dunér at first believed its spectrum to be IV. type, but afterwards thought it III. My observations of it are 1891 December 22 in moonlight IV., mag. 9·2. (The neighbouring star D.M. + 56°·725, mag. 9·0.) December 29 III.!! Spectrum faint; mag. 9·0. It was re-observed 1893 December 1, when I was at once struck with its increased brilliancy. It was then quite equal to D.M. + 56°·728, mag. 8·5. The spectrum type III.!! The star is variable.

(2) *Anonymous*, R.A. $19^h\ 16^m{\cdot}6$, Decl. + 37°41′ (1900). A fine red star near G.C. 6791. It is 9·0 mag., and evidently banded, and, I believe, type IV. It was detected on 1893 September 16, and up to November 13 was found constant in light. Its absence from the D.M. is suspicious, and it may be variable.

(3) *Anonymous*, R.A. $20^h\ 5^m{\cdot}0$, Decl. + 35°31′ (1900). A red star, mag. 10, found 1893 August 14, and showing a banded spectrum, which is possibly type IV.

(4) *Es. Birm* 654, R.A. $20^h\ 7^m{\cdot}3$, Decl. + 35°48′ (1900). A very red star of type IV., found by Pickering, who gives mag. 12, and thought it possibly variable. It was observed 1893 September 16, mag. 11·0, type IV., and on several other nights, the last December 2, and no variation seen. It was found on two photographs taken with the 8-inch 1893 April 13 and October 16, and so far appears constant.

(5) *Anonymous*, R.A. $20^h\ 12^m{\cdot}3$, Decl. + 37° 34′ (1900). A red star, mag. 10, found 1893 August 22. Banded spectrum, and possibly type IV.

(6) *Anonymous*, R.A. $20^h\ 13^m{\cdot}3$, Decl. + 36°36′ (1900). A red star, mag. 11·5, found 1893 September 16. Spectrum very faint, but pretty certainly banded, and believed to be type IV.

(7) *Es. Birm* 664, R.A. $20^h\ 17^m{\cdot}6$, Decl. + 36° 37′ (1900). This is D.M. + 36°·4025, and is the p. star of two. This star was re-examined on August 14, and found not to be type IV. but type III.!! The magnitude of the star in the D.M. is 9·5, and my observations suggest variability in its light. Using D.M. + 36°·4020, mag. 8·4; D.M. + 36°·4028, mag. 9·5, as comparison stars, my observations are:—

1885.	Mag.	1890.	Mag.
July 2	9·7	Aug. 15	8·5
		1893.	
,, 9	9·7	Aug. 14	8·4
1886.			
June 22	9·0	Aug. 24	8·4
Aug. 29	8·7	Sept. 16	8·6
1887.			
April 14	9·0	Dec. 1	8·2

On a photograph taken by Max Wolf, 1891, the estimated magnitude is 11·3, and on two photographs taken with the 8-in., mentioned under No. 4, the magnitudes are 12·5 and 12·2.

(8) RR. *Cygni*, $20^h\ 42^m{\cdot}6$, Decl. + 44°30′ (1900). As the spectrum of this star remains in doubt, it was examined on the nights of August 8, September 9, and was found to be III.!! The bands are large and ill-defined, but the character of the spectrum is undoubted.

(9) *Es. Birm* 706, R.A. $21^h\ 23^m{\cdot}3$, Decl. 62° 8′·4 (1900). This is D.M. + 61°·2134. In consequence of there being some uncertainty about the type, it was examined 1893 September 30, and found to be type III.!!

(10) D.M. + 60°·2432, $22^h\ 40^m{\cdot}4$, Decl. 61°12′ (1900), mag. 8·9. This star was encountered in sweeping 1893 October 8, and found to have a spectrum of type IV.

(11) *Es. Birm* 735, R.A. $22^h\ 43^m{\cdot}7$, Decl. + 54° 38′ (1900), mag. 9·5, D.M. + 58°·2863. On 1893 October 8 I examined this star, and found it had hitherto been wrongly identified as D.M. + 58°·2865. The spectrum is not IV. but III.!! My observations of its magnitude are:—

1887.	Mag.	1893.	Mag.
Oct. 20	8 5	Oct. 8	8 5
Dec. 4	8 2	11	8 3
Dec. 7	8·5	16	8·3
		Dec. 1	8·3

My observations are therefore very accordant, but still, the great difference between them and the D.M. magnitude suggests variation.

(12) *Es.* 141, R.A. $23^h\ 22^m{\cdot}2$, Decl. + 48°58′ (1900), mag. 9·3. This is D.M. + 48°·4051. The spectrum was observed for the first time on 1893 December 1, and found to be type IV., the three normal zones being well seen.

On the Orbit of α Centauri. By T. J. J. See, A.M., Ph.D. (Berlin).

(*Communicated by S. W. Burnham.*)

The orbit of *α Centauri* has been investigated so frequently in the last quarter of a century that the elements of this famous southern binary ought now to be well determined. But owing to the discordance of the older observations, even the recent orbits of Elkin * and Powell † give periodic times differing by

* *Inaug.-Dis., Ueber die Par. von α Cent.*, p. 8. † *M. N.* vol. xlv. p. 19.

more than ten years, while the other elements are of necessity correspondingly uncertain. Downing* considers the orbit of Elkin (with a periodic time of 77 years) essentially correct, and vigorously contests the claims of Powell, who insists upon a period of 88 years, which in turn is supported by the researches of Doberck.

The great interest attaching to *α Centauri* as the first revolving double star ever discovered, the one binary system where the components are of the first and second magnitudes, and at the same time the nearest of all the fixed stars, renders the investigation of its orbit of such profound interest, as to justify research that will materially advance our knowledge of this celebrated system. After all that has been done on the orbit of this star, there is evidently no hope of obtaining results of real value without making the investigation as thorough as the material at present available will permit.

In beginning this research it was therefore decided to collect all the measures from original sources, with the number of nights on which the measures were taken, and the number of observations entering into each mean result. In some cases, unfortunately, these data had not been recorded by the observers, and hence could not be obtained; while in a very few cases the observations had to be taken on the authority of other astronomers who have published lists of observations.

The material obtained, however, certainly includes everything of any value hitherto published, and is ample for the deduction of an orbit substantially correct.

The first observations of conspicuous worth are the micrometrical measures of Sir John Herschel, made during his residence at the Cape of Good Hope. The measures of Herschel taken in conjunction with measures recently made expressly for the purpose, have enabled us to determine the orbit of *α Centauri* with a degree of precision which is remarkable, when we consider the character of the observations. It will be found on inspecting the list of measures, that many of them are materially vitiated by errors of observation, some systematic, some accidental. In judging of the value of results, however, we must remember that *α Centauri* is a very bright star, so that the images are unusually large, and hence, unless the telescope is practically perfect and the atmospheric conditions are entirely satisfactory, it is hardly to be expected that the measures will be very accordant. We must also remember that there are no specialists in double-star work in the southern hemisphere, and hence we must not expect results such as could be obtained by the skill of a Burnham or a Struve. Of all the orbits hitherto found for *α Centauri*, only a few have now anything more than historical interest; some of the more recent elements are given in the following table.

* *M. N.* vol. xlv. p. 151.

Table of Elements of α Centauri.

P.	T.	e.	a.	Ω	λ.	i.	Authority.	Source.
79	1863 25	0·818	...	...	32·7	...	Jacob	*Ast. Nach.* Bd. xliv. p. 43.
82 59	1857 01	0·96	31·76	2·6	27·65	77·3	Powell	Mem. R. A. S. vol. xxiv. p. 93.
75·3	1858·01	0·966	30·0	177·83	27·4	77·83	Powell	„ „ „
85·042	1874·85	0·667	21·80	21·6	59·53	82·3	Hind	*M. N.* vol. xxxvii. p. 97.
77·42	1875·97	0·526	17 50	25·8	54 8	79·52	Elkin	Dissertation, p. 8.
88·536	1875·12	0·533	18 45	25 54	45·97	79·4	Doberck	
76·222	1875·95	0·516	17·33	25·51	54·99	79·25	Downing	*M. N.* vol. xliv. p. 239.
87·438	1875·45	0·5443	18·89	25·83	48·98	79·78	Powell	*M. N.* vol. xlvi. p. 337.
80·34	1875·74	0·526	17·20	25·22	52·5	79·53	Gill	Mem. R. A. S. vol. xlviii. p. 15.

In the following list will be found all the measures of *α Centauri* which are of any value, with the number of nights (n) on which the measures were made. The observations of T. Maclear, G. Maclear, and W. Mann, which were made about the middle of this century, are here taken from Dr. Elkin's *Inaugural Dissertation*, in which they were first printed; the number of nights on which these measures were made were kindly supplied by Dr. Elkin in a private letter. Most of the other measures are taken from the *Memoirs* and *Monthly Notices* of the Royal Astronomical Society.*

The writer desires to acknowledge his special obligations to Messrs. Tebbutt, Pickering, Douglass, Russell, Sellors, Gill, and Finlay for securing sets of measures of *α Centauri* expressly for the present research; also to thank Herr Hans Ludendorff, of the Royal Observatory, Berlin, for carefully confirming from the original sources the measures of Lacaille, Brisbane, Dunlop, and Johnson.

Observations of α Centauri.

t	δ	ρ	n	Observer.
1690·0	° ...	" ...	1	Richaud
1709·5	...	...	1	Feuillée
1752·20	218·73	20·51	...	Lacaille
1761·5	...	15·6	1	Maskelyne
1822·00	209·6	28·75	...	Fallows †
1824·00	215·41	22·45	35+	Brisbane
1826·01	213·18	22·45	...	Dunlop
1830·01	215·03	19·95	...	Johnson
1831·00	215·97	22·56	...	Taylor †
1832·16	216·35	19·85	...	Johnson & Taylor ‡
1833·0	217·45	18·67	7±	Henderson
1834·33	217·33	17·83	1	Herschel §
1834·45	218·78	17·50	2	Herschel
1835·08	218·80	17·33	1	Herschel
1835·89	219·59	17·02	11−1	Herschel
1836·61	220·26	16·76	1	Herschel
1837·22	220·65	16·39	4	Herschel

* The writer intended to have given in this paper the original source of each measure and the number of observations on which it is founded; but, as these data render the paper voluminous and are not essential to our present purpose, they are reserved for a future publication.

† Taken on the authority of Herschel.

‡ See Powell, *Monthly Notices*, 1855–56, p. 171.

§ Herschel's means have been formed anew.

t	δ	ρ	n	Observer.
	°	″		
1840·00	223·2	14·74	...	Maclear
1846·21	232·4	10·96	3	Jacob
1846·80	234·3	9·56	4	Jacob
1847·09	235·7	9·33	2–3	Jacob
1847·36	234·5	9·31	3	Jacob
1848·00	237·93	8·05	13–12	Jacob
1849·63	244·5	6·23	...	Jacob
1849·94	245·25	6·96	1	Maclear
1849·97	245·42	7·04	3–2	Maclear
1850·10	246·63	7·01	1	Maclear
1850·17	245·75	7·08	6	Maclear
1850·20	245·85	6·84	3	Maclear
1850·31	247·07	6·75	4	Maclear
1850·37	247·52	6·52	7	Jacob
1850·38	245·74	7·12	1	Maclear
1850·41	242·0	7·78	15	Gilliss
1850·61	248·84	6·58	3	Maclear
1850·64	249·1	6·20	7	Jacob
1850·92	250·27	5·88	6	Jacob
1850·94	251·84	6·02	3	Maclear
1851·02	251·05	5·88	8	Jacob
1851·08	252·50	6·12	3	Maclear
1851·20	252·13	5·94	10–8	Jacob
1851·33	253·92	6·02	5	Maclear
1851·56	254·42	5·88	3	Maclear
1851·70	256·38	5·27	8	Jacob
1851·94	256·58	5·80	3	Maclear
1851·94	258·2	5·11	9–8	Jacob
1851·99	258·85	5·08	8–7	Jacob
1852·25	259·02	5·72	3	Maclear
1852·27	261·07	5·03	7	Jacob
1852·38	261·88	4·94	6	Jacob
1852·43	261·67	5·27	5	Maclear
1852·53	264·16	5·00	4	Jacob
1852·56	262·8	5·03	...	Maclear
1852·58	262·89	5·18	7–9	Maclear
1852·73	262·45	4·95	5–2	Maclear
1852·79	263·31	...	4	Maclear

t	θ	ρ	n	Observer.
1853·05	267°·67	4″·55	...	Jacob
1853·13	266·54	4·84	4–6	Maclear
1853·15	268·33	4·59	...	Jacob
1853·34	268·72	4·87	5	Maclear
1853·50	271·03	4·68	6	Maclear
1853·58	272·17	4·57	2–1	Mann
1853·58	270·10	...	...	Powell
1853·92	275·19	4·44	4–3	Maclear
1854·00	276·63	4·21	...	Jacob
1854·03	276·85	...	7	Powell
1854·24	278·98	4·62	4	Maclear
1854·25	279·06	4·16	2	Jacob
1854·26	279·62	...	4	Powell
1854·63	283·44	...	3	Powell
1854·66	282·81	4·43	5	Maclear
1854·93	285·88	3·96	5–4	Maclear
1854·96	288·02	...	2	Powell
1855·06	289·32	...	10	Powell
1855·23	290·19	4·38	3	Maclear
1855·29	292·60	...	5	Powell
1855·33	293·8	4·11	10	Powell
1855·36	291·96	4·38	4	Maclear
1855·54	294·73	...	5	Powell
1856·02	301·02	3·99	11–6	Powell
1856·02	302·13	3·85	7–6	Maclear
1856·10	303·06	3·88	18	Jacob
1856·38	306·92	4·05	1	Maclear
1856·51	309·84	3·93	10–9	Jacob
1856·91	311·26	4·21	4	Mann
1856·94	311·88	...	11	G. Maclear
1856·95	310·78	4·05	6	Mann
1856·96	315·77	3·96	10–9	Jacob
1857·15	318·19	4·02	15	Jacob
1857·39	320·60	4·47	2–1	Maclear
1857·86	326·48	4·14	14	Jacob
1858·17	330·51	4·39	5	Jacob
1858·23	339·42	5·09	3	Maclear
1859·34	339·71	5·18	15–12	Powell

t	δ	ρ	n	Observer.
1859·43	343°·44	5″·10	5	Mann
1859·52	341·8	4·92	4	Powell
1859·97	346·08	5·00	3	Mann
1860·05	346·55	...	1	G. Maclear
1860·09	345·4	5·65	17−13	Powell
1860·18	349·34	5·52	4−1	Maclear
1860·35	348·87	...	3	Maclear
1860·48	348·7	5·68	1	Powell
1861·05	351·08	6·07	10−9	Powell
1861·09	353·65	6·09	3	Maclear
1861·31	353·03	6·21	7	Powell
1861·58	354·26	6·32	5−3	Powell
1862·0	0·0	10·0	...	Ellery*
1862·20	357·84	6·80	7	Powell
1862·47	0·0	...	...	Ellery†
1862·56	1·38	7·55	3	Maclear
1863·03	1·4	7·2	6−4	Powell
1863·75	5·2	8·5	...	Ellery
1864·11	5·7	7·85	7−5	Powell
1864·72	...	8·1	...	Ellery
1865·56	17·3	9·95	1	Ellery†
1866·06	11·1	9·3	3	Powell
1868·17	...	9·2	...	Ellery
1868·18	...	9·6	...	Ellery
1868·38	13·59	10·29	2	Mann
1868·51	21·8	11·02	5	Ellery†
1869·13	17·97	10·4	2	Powell
1870·1	20·45	10·24	13−12	Powell
1870·61	21·8	10·09	5-4	Powell
1870·65	...	10·2	...	Ellery
1870·65	24·7	10·45	3	Ellery†
1870·75	22·53	10·46	4	Russell
1871·05	23·01	9·89	11	Powell
1871·31	23·7	9·8	7	Powell
1871·48	22·91	10·22	2	Russell
1871·51	24·2	9·41	1	Ellery

* Apparently a rough "guess." † From transit observations.

t	δ	ρ	n	Observer.
1872·47	25°·31	9″·73	2	Russell
1872·55	24·1	10·36	1	Ellery
1873·16	...	8·3	...	Ellery
1873·33	28·1	9·50	1	Russell
1874·15	30·5	8·0	...	Ellery
1874·47	30·0	7·97	2	Russell
1874·85	34·17	...	...	Lindsay
1875·02	34·21	6·82	...	Seeliger
1875·94	39·3	6·68	1	Ellery *
1876·41	46·97	4·35	2	Russell
1876·61	51·05	4·15	2	Ellery
1876·90	64·3	4·94	1	Ellery
1876·94	51·2	4·5	1	Ellery
1877·14	64·4	3·30	...	Maxwell Hall
1877·25	69·1	3·13	5	Ellery
1877·52	72·77	2·60	2–1	Russell
1877·56	77·25	2·11	3	Russell
1877·57	80·50	2·13	2–3	Gill
1877·59	81·74	1·90	3	Russell
1877·63	81·49	1·94	3–1	Gill
1877·82	97·12	1·85	2–3	Gill
1877·89	101·12	1·62	2	Gill
1878·16	116·98	1·77	1	Russell
1878·22	119·82	1·95	3	Russell
1878·28	127·37	1·77	1	Russell
1878·38	139·10	2·40	...	Maxwell Hall
1879·25	174·40	3·41	...	Ellery
1879·47	173·55	3·41	2	Hargrave
1880·18	183·9	5·22	4	Tebbutt
1880·39	185·2	5·56	3	Tebbutt
1880·45	184·98	5·52	1	Russell
1881·28	189·88	5·07	1	Hargrave
1881·54	190·13	7·52	1	Hargrave
1881·65	193·15	7·94	2	Tebbutt
1882·00	194·44	8·23	18	Gill
1882·22	194·6	8·70	1	Tebbutt
1882·50	195·82	9·12	52	Elkin
1884·19	199·0	11·96	...	Russell

* From transit observations.

t	θ	ρ	n	Observer.
	°	"		
1884·43	199·5	12·32	...	Russell*
1884·53	199·80	12·93	6	Tebbutt
1885·56	200·8	14·05	4–3	Tebbutt
1886·27	202·5	14·89	5	Pollock
1886·38	200·4	14·74	1	Russell
1886·52	201·2	15·19	1	Russell
1886·55	201·02	14·87	4	Pollock*
1886·56	202·42	15·13	10	Pollock
1886·58	201·7	15·18	3	Russell
1886·60	201·41	15·16	4	Tebbutt
1887·39	202·3	16·06	3–5	Tebbutt
1887·43	202·08	15·83	6–5	Pollock
1887·60	202·35	16·28	3–2	Tebbutt
1887·72	202·16	16·18	2	Tebbutt
1887·74	203·0	15·73	4	Pollock
1888·30	203·4	16·87	3	Tebbutt
1888·63	202·93	17·12	1	Tebbutt
1889·45	204·5	17·91	3	Pollock
1890·41	205·2	18·58	2	Tebbutt
1890·47	204·75	18·66	4–3	Sellors
1890·60	205·05	19·06	3–2	Sellors
1890·74	204·6	18·69	1–3	Tebbutt
1891·43	205·62	19·15	5–4	Sellors
1891·56	207·17	19·25	4–2	Tebbutt
1891·57	205·3	19·24	2	Sellors
1891·64	206·4	19·35	3–6	Tebbutt
1892·30	206·45	19·52	2	Gill & Finlay †
1892·40	205·46	19·73	5–4	Sellors
1892·45	205·53	19·75	7–4	Tebbutt
1892·58	205·83	19·73	8–5	Tebbutt
1892·76	206·9	19·96	1	W. H. Pickering †
1893·21	206·9	20·04	1	A. E. Douglass
1893·21	206·75	20·22	2–1	W. H. Pickering
1893·34	206·4	19·92	8	Sellors
1893·42	206·73	20·32	6–4	Tebbutt
1893·49	206·5	20·24	8	Sellors
1893·50	206·75	20·53	4–2	Tebbutt

* From $\Delta\alpha$ and $\Delta\delta$. † By photography.

After carefully inspecting the foregoing list of measures, we have formed the following mean results, which are referred to the meridian of 1900·0.

Mean Measures of α Centauri, with corresponding Computed places.

Epoch.	Angle.		Distance.		No. Nights
t	δo	δc	ρo	ρc	n
	°	°	″	″	
1690·0	...	257·62	...	5·23	1
1709·5	...	24·30	...	10·07	1
1752·2	217·84	216·66	20·51	18·30	...
1822·0	209·05	211·00	28·75	21·86	...
1824·0	214·88	211·90	22·45	21·57	35+
1826·01	212·66	212·83	22·45	21·10	...
1830·01	214·54	214·87	19·95	19·72	...
1831·0	215·49	215·42	22·56	19·29	...
1832·16	215·87	215·73	19·85	19·04	...
1833·0	216·98	216·62	18·67	18·33	7±
1834·33	216·87	217·50	17·83	17·63	1
1834·45	218·32	217·57	17·50	17·56	2
1835·08	218·35	217·70	17·33	17·46	2−1
1835·89	219·14	218·62	17·02	16·74	11−1
1836·61	219·82	219·17	16·76	16·30	1
1837·22	220·21	219·67	16·39	15·93	4
1840·0	222·78	222·30	14·74	14·11	...
1846·21	232·02	232·02	10·96	9·54	3
1846·80	233·93	233·47	9·56	9·08	4
1847·09	235·33	234·22	9·33	8·87	2−3
1847·36	234·13	234·92	9·31	8·67	3
1848·00	237·57	236·90	8·05	8·16	13−12
1849·63	244·15	243·02	6·23	6·93	...
1849·95	244·98	244·47	7·00	6·70	4−3
1850·20	244·97	245·70	6·92	6·52	14
1850·38	246·28	246·63	6·82	6·38	8
1850·41	241·65	246·77	7·78	6·36	15
1850·62	248·62	247·90	6·39	6·22	10
1850·93	250·7	249·65	5·95	5·99	10−9
1851·10	251·55	250·68	5·98	5·88	21−19
1851·44	253·33	252·85	5·95	5·65	8
1851·87	256·14	255·87	5·53	5·37	11

Epoch.	Angle.		Distance.		No. Nights.
t	δ_o	δ_c	ρ_o	ρ_c	
	°	°	″	″	
1851·95	258·18	256·47	5·09	5·32	17–15
1852·33	260·58	259·43	5·24	5·09	21
1852·64	262·78	262·10	5·03	4·90	20–15
1853·27	268·73	268·07	4·69	4·57	17–18
1853·75	272·32	273·20	4·44	4·35	4–3
1854·16	277·91	278·00	4·33	4·19	13–6
1854·79	284·72	286·02	4·19	4·00	15–9
1855·25	291·26	292·28	4·29	3·91	32–17
1856·13	302·97	304·70	3·94	3·87	42–31
1856·51	309·84	310·05	3·93	3·91	10–9
1856·94	312·11	315·93	4·07	3·98	41–19
1857·27	319·09	320·27	4·24	4·07	17–16
1857·86	326·18	327·50	4·14	4·27	14
1858·17	330·22	330·99	4·39	4·41	5
1859·33	340·6	342·10	5·12	4·99	23–20
1859·52	341·52	343·80	4·92	5·11	4
1859·97	345·8	347·27	5·00	5·39	3
1860·27	347·78	349·40	5·62	5·58	26–15
1861·07	352·09	354·38	6·08	6·10	13–12
1861·44	353·38	356·50	6·26	6·36	12–10
1862·41	359·47	0·05	7·17	7·02	10
1863·03	1·14	3·57	7·2	7·44	6–4
1863·75	4·95	5·15	8·5	7·92	...
1864·11	5·55	6·33	7·85	8·16	7–5
1864·72	...	8·20	8·1	8·54	3±
1865·56	17·06	11·50	9·95	9·12	1
1866·06	10·86	12·75	9·3	9·32	3
1868·38	13·37	17·85	10·29	10·28	2
1868·51	21·58	18·10	11·02	10·31	5
1869·13	17·75	19·33	10·4	10·42	2
1870·1	20·24	21·20	10·24	10·47	13–12
1870·61	21·59	22·20	10·09	10·41	5–4
1870·65	24·5	22·28	10·32	10·40	3–5±
1870·75	22·33	22·66	10·46	10·35	4
1871·18	23·15	23·33	9·84	10·26	18
1871·49	23·35	24·15	9·82	10·10	3
1872·51	24·51	26·20	10·04	9·53	3

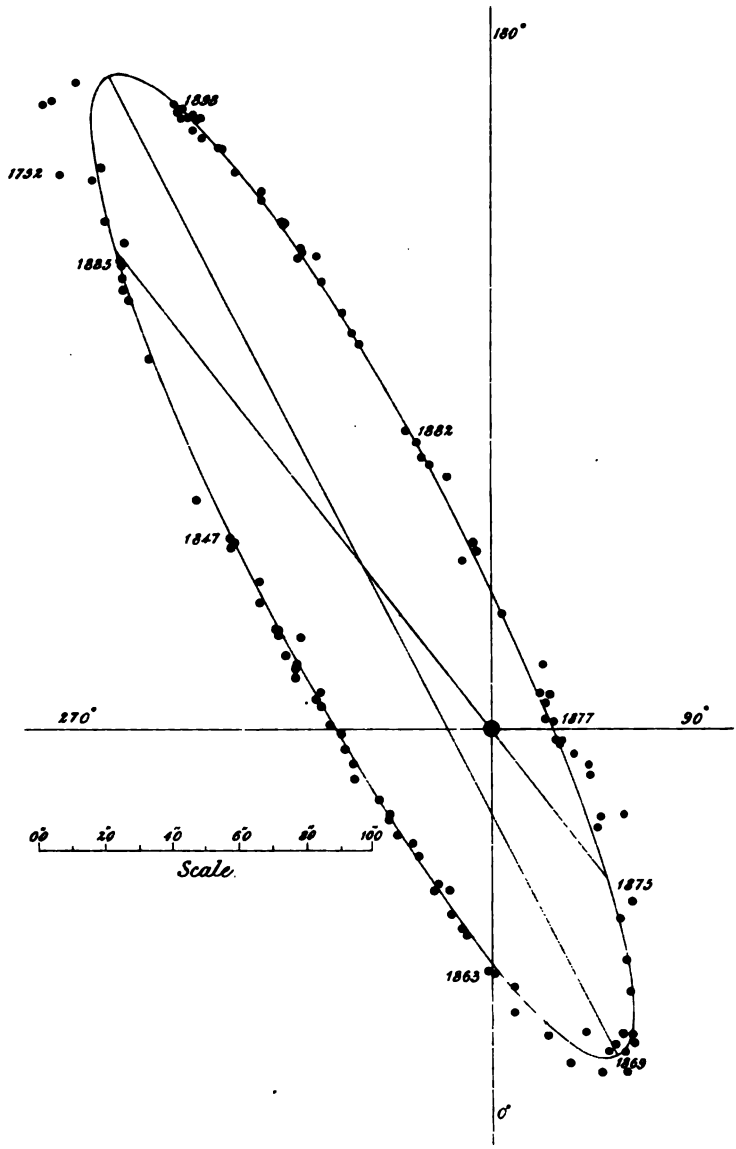
Epoch.	Angle.		Distance.		No. Nights.
t	δ_o	δ_c	ρ_o	ρ	n
1873·25	27°·91	28°·05	8″·90	8″·86	1−3 ±
1874·31	30·07	31·38	7·98	7·55	3−4 ±
1875·02	34·04	34·45	6·82	6·46	...
1875·94	39·13	40·68	6·68	4·83	1
1876·41	46·80	45·93	4·35	3·94	2
1876·61	50·89	48·97	4·15	3·56	2
1876·92	57·09	55·17	4·72	2·98	2
1877·14	64·4	61·23	3·30	2·59	...
1877·25	68·94	64·99	3·13	2·41	5
1877·52	72·61	76·85	2·60	2·01	2−1
1877·56	77·09	79·00	2·11	1·96	3
1877·57	80·34	79·58	2·13	1·95	2−3
1877·59	81·58	80·70	1·90	1·92	3
1877·63	81·33	83·06	1·94	1·88	3−1
1877·82	96·97	95·43	1·85	1·71	2−3
1877·89	100·97	100·93	1·62	1·67	2
1878·16	116·83	122·15	1·77	1·65	1
1878·22	119·67	126·78	1·95	1·68	3
1878·28	127·12	131·17	1·77	1·72	1
1878·38	138·95	138·05	2·40	1·80	...
1879·25	174·25	172·72	3·41	3·14	...
1879·47	173·41	176·90	3·41	3·56	2
1880·18	183·76	185·47	5·22	4·95	4
1880·39	185·06	187·15	5·56	5·36	3
1880·46	184·84	187·43	5·52	5·43	1
1881·28	189·75	192·13	5·07	7·06	1
1881·54	190·00	193·18	7·52	7·54	1
1881·65	193·02	193·58	7·94	7·75	2
1882·00	194·44	194·72	8·23	8·38	18
1882·22	194·48	195·35	8·70	8·77	1
1882·50	195·82	196·08	9·12	9·25	52
1884·19	198·89	199·32	11·96	11·93	...
1884·43	199·39	199·66	12·32	12·27	...
1884·53	199·69	199·75	12·93	12·36	6
1885·56	200·7	201·08	14·05	13·80	4−3
1886·27	202·4	201·83	14·89	14·67	5
1886·38	200·3	202·08	14·74	14·80	1

Epoch.	Angle.		Distance.		No. Nights.
t	δ_o	δ_c	ρ_o	ρ_c	n
1886·54	201°·46	202°·13	15″·06	14″·98	15
1886·59	201·46	202·87	15·17	15·04	7
1887·41	202·1	203·10	15·95	15·93	9–10
1887·69	202·31	203·57	16·07	16·22	9–8
1888·30	203·32	203·80	16·87	16·82	3
1888·63	202·85	204·38	17·12	17·12	1
1889·45	204·43	205·03	17·91	17·83	3
1890·49	204·93	205·20	18·77	18·63	9–7
1890·74	204·53	205·63	18·69	18·80	1–3
1891·50	206·01	206·03	19·25	19·31	14
1892·30	206·45	206·13	19·52	19·73	2
1892·40	205·40	206·15	19·73	19·79	5–4
1892·45	205·53	206·17	19·75	19·82	7–4
1892·58	205·83	206·23	19·73	19·86	8–5
1892·76	205·9	206·33	19·96	19·93	1
1893·21	206·9	206·53	20·04	20·03	1
1893·21	206·75	206·53	20·22	20·03	2–1
1893·34	206·4	206·56	19·92	20·18	8
1893·42	206·73	206·57	20·32	20·25	6–4
1893·49	206·5	206·65	20·24	20·34	8
1893·50	206·75	206·68	20·53	20·35	4–2

Ephemeris of α Centauri.

t	δ	ρ	t	δ	ρ
1894·50	207°·22	20″·81	1903·50	211°·30	21″·79
1895·50	207·70	21·16	1904·50	211·73	21·64
1896·50	208·17	21·44	1905·50	212·20	21·44
1897·50	208·62	21·66	1906·50	212·65	21·20
1898·50	209·07	21·82	1907·50	213·13	20·93
1899·50	209·52	21·92	1908·50	213·62	20·62
1900·50	209·98	21·96	1909·50	214·13	20·26
1901·50	210·40	21·95	1910·50	214·67	19·88
1902·50	210·83	21·89			

From these mean results the orbit will now be deduced. The observations are accurately platted on large drawing paper by means of a protractor, and we thus obtain a series of points through which the ellipse must pass as a sort of interpolating curve. Errors of observation of course prevent the points from


180°
1898
1732
1885
1882
1847
270°
1877
90°
0° 2° 4° 6° 8° 10°
Scale.
1875
1863
1869
0°

α Centauri

falling exactly on the arc of any true ellipse, and all that can be done is to pass the ellipse through the points so as to conform to the best observations. If the ellipse is judiciously drawn, we shall thereby eliminate not only accidental errors (as in the method of Least Squares), but also to a considerable extent free the measures from systematic errors, which are in general so troublesome in the adjustment of observations, and for the elimination of which the method of Least Squares is of no avail. By inspecting the apparent orbit, we see that the ellipse (which has been drawn with the greatest possible accuracy) satisfies the observations as a whole remarkably well; and in the deviations of the observations from the ellipse, we see the visible effects of systematic errors. The systematic errors of distance are conspicuous between 1822 and 1835; 1863 and 1870, where Ellery's distances are evidently too large; and 1875 and 1880, where the distances are generally over-estimated. There are analogous systematic errors in the position angles at different points of the orbit, but these can best be seen by inspecting the table of computed and observed places. The accompanying ellipse represents the observations as satisfactorily as could be desired, and therefore we do not hesitate to affirm that the elements deduced from this apparent orbit will be as good as can be obtained at the present time.* The elements here adopted have been determined directly from the apparent orbit by the method of Klinkerfues. In the present state of double-star astronomy, it is superfluous to attempt corrections of a very minute character, because the range of uncertainty is always considerable and there is no means of determining the true orbit with absolute rigour, since all the observations are necessarily more or less erroneous.

The following are the

Elements of a Centauri.

$P = 81{\cdot}07$ years	$i = 79°{\cdot}74$
$T = 1875{\cdot}62$	$\lambda = 51°{\cdot}56$
$e = 0{\cdot}52$	$a = 17''{\cdot}705$
$\Omega = 25°{\cdot}45$ (1900·0)	$n = +4°{\cdot}44184$

Apparent orbit:

Length of major axis = 32″·50
Length of minor axis = 6″·16
Angle of major axis = 27°·2
Angle of Periastron = 38°·0
Distance of star from centre = 5″·94

* The reader is referred to a paper in *Astronomy and Astro-Physics* for 1893 December, in which the writer shows that in general a Least-Square

If we adopt the parallax of Gill and Elkin (0″·75), we find that the major axis of the orbit of *α Centauri* is 23·592 astronomical units; from which it follows that the combined mass of the components is 1·998 times the mass of the Sun and Earth, or sensibly twice the mass of the Sun. Thus we see that the companion of *α Centauri* moves in an orbit with a major axis which is about a mean between those of the planets *Uranus* and *Neptune*; but the orbit is so eccentric that in *Periastron* the two stars are only slightly remoter than the Sun and *Saturn* (11·3), while in *Apastron* the distance considerably surpasses that of *Neptune* from the Sun (36·0).

According to the preliminary reseaches * of Stone the masses of the two components of *α Centauri* are approximately equal. As it would be a matter of great scientific interest to determine this mass-ratio by means of more recent data, it had been the intention of the writer to embody the results of such a research in the present paper, but as new measures of the positions of the components are now being made at the Cape of Good Hope, it will be advisable to reserve the investigation of the centre of gravity for some future occasion. The great cosmogonic interest attaching to binary systems ought to induce astronomers to determine wherever possible the mass-ratio of the components, as the results will throw important light upon the problem of the formation and development of double stars. If the relative masses and the eccentricity can be determined with the desired degree of precision, the data thus obtained will not only be useful in fundamental astronomy, but will also furnish a firm foundation for future research in stellar cosmogony.

In conclusion, the writer desires to acknowledge his special obligations to Mr. J. W. Froley, M.Sc., Fellow in Astronomy at the University of Chicago, for valuable assistance in the calculations embodied in this paper; also to thank Mr. S. W. Burnham for generous advice and assistance in collecting the long list of observations.

The University of Chicago:
1893 *August* 1.

Note.

Since the foregoing paper was finished, an important article on the orbit of *α Centauri*, by Mr. A. W. Roberts, has appeared in the *Astronomische Nachrichten*, No. 3,175. The results are almost identical with those obtained here, but as the two sets

adjustment is impracticable (owing to the absence of condition underlying the theory of Least Squares), and that it is also inadvisable to employ graphical interpolating curves to correct the angles or distances. The course here adopted is there fully discussed and justified.

* *Monthly Notices*. 1875-6, p. 259.

of elements are independent of each other and were obtained by very different methods, the coincidence can only indicate that the elements found are very near the truth. We may confidently believe that the orbit of *α Centauri* is now as well known as that of any binary star in the heavens. If in the course of time any corrections shall be required for the elements given above, it is certain that the changes will of necessity be very small.

The University of Chicago :
1893 *August* 30.

The Periodic Variation in the Motion of 61 Cygni.

By Harold Jacoby, B.A.

The important discovery by Dr. Wilsing * of a periodic variation in the distance of the components of 61 *Cygni* is of so great interest that it would seem desirable to re-examine the Oxford measures, to see whether additional evidence can be found. The late Professor Pritchard did not measure the distance between the two components directly, as was done at Potsdam. But in his parallax determination he employed two comparison stars (*a* and *b*), which lie very nearly on the great circle joining the two components of 61 *Cygni*. As the distance from each of these comparison stars to such component was always independently measured, we have but to perform a subtraction to get what is very nearly the distance between the two components. In fact, Professor Pritchard himself computed such "differences" for another purpose, and they are printed in his *fasciculus* iii., p. 24, for star *a*, and p. 37 for star *b*. They ought to exhibit a variation similar to that found by Dr. Wilsing from the Potsdam plates. In examining whether such is the case, I have thought it best to treat the results from stars *a* and *b* independently. Professor Pritchard gives also the excess of the mean of all the "differences" over each individual one. I have united these into general means; and to avoid any bias in selecting the several groups for this purpose, I have taken each calendar month by itself, except that the plates of 1886 May 26, 28, 30, and July 1, were included in the group for 1886 June. These were the only plates made in those two months, and their number was too small to use them separately. It is evident that the numbers so obtained will be positive when the distance of the components of 61 *Cygni* is small, and negative when it is large, as compared with its mean value. In this way I find the fol-

* *Kgl. Akad. d. Wissensch. zu Berlin, Sitzungsb.* xl., p. 879, 1893 Oct. 26.

lowing as the excess of the mean distance over that actually observed.

1886. Date.	No. of Plates.	Star *a*.	Star *b*.
June	52	″·00	+·05
Aug.	28	−·07	−·02
Sept.	52	−·01	−·06
Oct.	20	−·01	+·11
Nov.	28	−·03	+·01
Dec.	32	+·01	+·06
1887. Jan.	28	+·10	+·05
Feb.	24	+·11	−·15
Mar.	16	+·08	−·04
April	32	−·10	−·08
May	44	−·01	+·05

This table indicates, with comparatively good agreement between the two independent determinations *a* and *b*, that the distance of the components of 61 *Cygni* was less in 1887 January than it had been in 1886 September by about 0″·12. Just such a diminution of the distance in four months was found by Dr. Wilsing to precede minima in 1891 June and 1893 April. Moreover, Professor Pritchard's results agree fairly well with Dr. Wilsing's in showing an indication of steadiness for some months preceding the minimum, and a sharp rise, with perhaps a subsequent slight fall, some three months or so after the minimum. If the minimum observed at Oxford is taken to have occurred in 1887 January, we can compare it with Dr. Wilsing's of 1893 April, to determine the period. The interval would give a period of twenty-five or nineteen months, according to whether we assume that three or four periods had elapsed. Dr. Wilsing makes the period twenty-two months from his own two observed minima. The period may therefore be variable.

On the whole we may conclude that the above evidence furnished by the Oxford observations is favourable to the reality of Dr. Wilsing's discovery. I have also examined in a similar way the Oxford measures of the comparison stars *c* and *d*, which are situated in a direction approximately at right angles to the great circle joining the two components of 61 *Cygni*. The numbers, however, come out smaller, and with more frequent changes of sign, so that no conclusion can properly be drawn from them.

Columbia College Observatory, New York:
1893 *November* 27.

The Orbit of γ Andromedæ BC. By S. W. Burnham, M.A.

For nearly forty years after the discovery of this pair by Otto Struve in 1842, the measures failed to show any considerable change in either angle or distance. The observations are very discordant, and for many years it was impossible to say anything more than that an increase in the distance of perhaps one or two tenths of a second was probable; while change in the angle was at least doubtful so far as the measures were concerned. Some ten years ago it was evident that the distance was decreasing, and it finally came to be regarded as single in most telescopes. I found it very close with 36-inch refractor at Mount Hamilton, but made some measures of both angle and distance in 1889, and again in 1891 obtained three fairly satisfactory measures of the angle, the distance being estimated at not more than 0″·05. It was also examined in 1888 and 1890, but the star was too close, or the conditions too unfavourable, to make it possible to get any measures.

From the uncertain and discordant character of the earlier measures, it was impossible to tell to which quadrant the smaller component belonged in my measures of 1891, and therefore the form of the apparent orbit was still uncertain. During the past summer I requested Professor E. E. Barnard to observe this pair with the 36-inch telescope, and especially to be certain of the quadrant. I have recently received from him his measures, made on two nights under favourable conditions. On both occasions he was absolutely certain that the smaller component was on the following side. The stars were well separated with a power of 2,600, and the difference in magnitude was unmistakable. I have given the highest value to these measures.

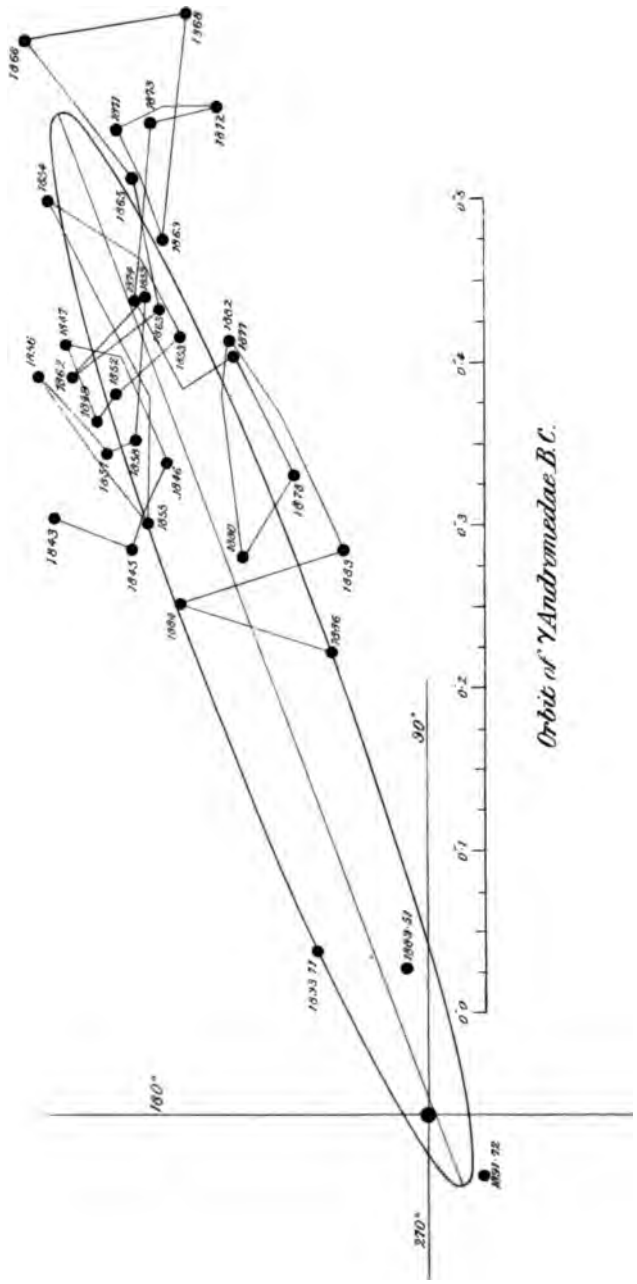
This position furnishes the key to the situation, and without it would be impossible to even guess at the form of the apparent orbit. With the large arc passed over by the smaller star, a reasonably good provisional orbit should now be obtained. According to the Mount Hamilton measures, this star has moved about 330° in the last four years.

The following are the measures of this pair:

Measures of γ Andromedæ BC. (0ℌ 38).

1843·00*	119°·7	0″·45 ±	2n	Dawes
·19*	119·8	0·35	2–1	Mädler
·55*	125·5	0·48	3	O. Struve
1845·15*	116·9	0·39	4	Mädler
1846·64*	111·3	0·43	7–3	Mitchel
1847·13*	117·9	0·52	5	O. Struve

1847·82*	111°·3	0″·6 ±	4*n*	Dawes
1849·69*	114·9	0·47	4	O. Struve
1851·19	116·6	0·40	4	Mädler
1852·21*	114·5	0·48	2	Mädler
·78*	111·3	0·5 ±	2	Jacob
1853·23*	116·0	0·47	3	Mädler
·79*	108·5	0·55 ±	4	Dawes
·94*	106·8	0·4 ±	4	Jacob
1854·75*	112·0	0·61	1	Dawes
1855·02*	119·4	...	1	Mädler
·09*	109·8	0·40	1	Secchi
1856·12*	116·7	0·5 ±	1	Jacob
·20*	116·5	0·45	1	Mädler
·21*	121·7	0·41	2	Winnecke
·84*	113·0	0·67	3	O. Struve
·90*	109·7	0·47	3	Secchi
1857·23*	115·4	0·45	3–1	Mädler
1858·06*	114·0	...	2	Jacob
·22*	115·4	...	2	Mädler
·99*	108·9	0·45	3	Secchi
1859·81*	108·7	0·53	1	Dawes
1862·55*	115·2	0·50	4–2	Mädler
1863·27*	108·5	0·45 ±	8	Dembowski
·86*	107·7	0·59	1	Dawes
·99*	107·6	0·61	...	Romberg
1865·67*	107·1	0·59	4	Knott
·68*	106·9	0·60	1	Dawes
·76*	106·3	0·58	2–1	Talmage
1886 21*	110·0	0·70	3	O. Struve
·74	132·3	...	1	Winlock
·74	107·2	...	1	Searle
·74	100·4	...	1	Winlock
·85	104·2	0·64	1	Talmage
1867·79	104·3	0·5 ±	1	Newcomb
1868·82*	102·0	0·69	6–5	Brunnow
1869·84*	107·0	0·63	3	O. Struve
·95*	105·6	0·5 ±	13	Dembowski
1871·01*	110·6	0·63	15	Dunér


Orbit of γ Andromedae B.C.
180°
270°
30°
0·0
0·1
0·2
0·3
0·4
0·5
1966
1968
1871
1853
1872
1854
1863
1852
1877
1878
1843
1845
1856
1846
1855
1867
1883
1869
1876
1833·71
1869·51
1837·32

1872·83*	101°·5	0″·63	4–2n	Brunnow
·92	91·8	0·5 ±	2–1	Wilson & S.
1873·17*	105·4	0·63	5	O. Struve
1874·00*	109·3	0·53	1	Newcomb
·53	96·3	0·51	2	Gledhill
1876·79	105·7	...	1	Wilson & S.
1877·05*	104·1	0·48 ±	6	Schiaparelli
·71	103·9	...	1	Doberck
·94	102·4	0·84	1	Seabroke
1878·21*	101·0	0·36	8	Hall
·65*	102·1	0·43	2	Burnham
1880·06*	107·9	0·36	1	Burnham
·11	106·7	...	2	Seabroke
·12	94·1	...	8	Jedrzejewicz
1882·05*	104·0	0·49	6–1	Bigourdan
1883·15*	93·1	0·29	7	Engelmann
·16	106·7	...	1	Seabroke
·87*	103·1	0·40	2	Perrotin
1884·18*	113·3	...	3	Seabroke
·65*	117·6	0·35	1	Perrotin
1886·83*	101·0	0·29	1	Newcomb
1889·51*	98·2	0·09	1	Burnham
1891·72*	312·6	0·05 ±	3	Burnham
1893·71*	123·4	0·12	2	Barnard

Mr. Gledhill, in his *Handbook of Double Stars*, gives two measures of this pair by Challis as follows:

1842·84	106°·3	0″·15
1843·31	115·8	0·31

I have not been able to refer to the original publication containing these observations, but as one of the angles must be erroneous, and the distances impossible, I have omitted them in the foregoing table.

The measures shown on the accompanying diagram (Plate 4) are marked with an asterisk (*), and the consecutive positions connected by lines to show the order of time in which the observations were made. When more than one observation in a year is used, a simple mean is taken. It will be seen at once that the measures as a whole are inconsistent and uncertain to an extraordinary degree. Evidently some of them are little, if any,

better than careful estimates. The distances in this instance seem to be almost as doubtful as the angles, which is very unusual in a pair of this kind. These large errors are all the more remarkable for the reason that from the beginning of the observations down to less than ten years ago this has been a comparatively easy pair, even with telescopes of very moderate aperture.

In finding the apparent orbit, it has been necessary to be governed largely by the more recent measures. After various trials, the ellipse shown on the diagram was adopted as the best that could be found to satisfy the law of areas in respect to the intervals between the late measures and the general group of earlier positions. It is satisfactory in this respect, and should give as good approximate elements as can be found from the present data.

From the apparent orbit we have the following elements:

$P = 54{\cdot}8$ years	$i = 78°{\cdot}9$
$T = 1892{\cdot}1$	$\Omega = 113°{\cdot}5$
$e = 0{\cdot}875$	$\lambda = 200°{\cdot}8$
$a = 0''{\cdot}37$	

Apparent Orbit.

Length of major axis	=	$0''{\cdot}697$
Length of minor axis	=	$0''{\cdot}077$
Angle of major axis	=	$110°{\cdot}0$
Angle of periastron	=	$289°{\cdot}3$
Star from centre	=	$0''{\cdot}30$

According to this orbit, the distance should steadily increase, the position-angle changing very slowly from year to year. It will soon be readily measurable with ordinary refractors.

Chicago:
1893 *November* 15.

Windsor Measures of α Centauri in 1893. By John Tebbutt.

The following measures of α Centauri were taken with the 8-inch equatorial at the request of Professor T. J. J. See, of Chicago. As there will probably be no other double-star observations from this observatory for the current year, I deem it advisable to send them at once for publication in the *Monthly Notices*. In all the observations east of the meridian the line joining the observer's eyes was parallel to that joining the components, but in those west of the meridian these lines were at right angles. The scale of weights is from one to five, one denotes the worst, and five the best conditions possible.

Date of Obs.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Hour Angles between which the measures were made.		Weight 1–5.
1893.						h m	h m	
·411	...	...	20·42	10	170	2 45 E	2 20 E	2
·411	206·3	10	...	...	230	1 53 E	1 40 E	2
·416	207·0	10	...	...	230	0 25 E	0 10 E	2
·419	206·8	10	20·02	10	230	2 31 E	1 51 E	3
·422	206·3	10	20·25	10	300	3 20 E	2 46 E	4
·427	206·9	10	...	...	300	0 29 E	0 0	4
·430	207·1	10	20·59	7	300	2 31 E	1 40 E	4
·493	207·7	10	20·60	8	300	1 53 W	2 22 W	2
·496	206·4	10	20·45	8	300	0 54 W	1 27 W	3
·498	207·0	10	...	...	300	1 40 W	1 56 W	1
501	205·9	10	...	...	300	0 22 W	0 38 W	1

Weighting each result according to the conditions under which it was obtained, we have the following mean:

Epoch = 1893·442. Position angle = 206″·8. Distance = 20″·38.

Private Observatory,
The Peninsula, Windsor, N.S. Wales:
1893 October 27.

Observations of Double Stars made at Sydney Observatory.

(*Communicated by H. C. Russell, B.A., F.R.S., Government Astronomer.*)

The following list of double stars, believed to be new pairs, were found by Mr. R. P. Sellors between 1890 March and 1893 October, in the course of his double-star work with the 11½-inch refractor of Sydney Observatory.

No.	No. in Merid. Cat.	R.A. 1900. h m	S. Decl. 1900. ° ′	Epoch.	P. Angle. °	Dist. ″	Mags.
1	β Phœnicis	1 2	47 15	91·969	26·3	0·93	4–4
	St. 430	...	...	92·895	24·7	0·90	
				92·947	24·1	0·90	
				92·953	24·3	0·97	
2	St. 448	1 4	47 12	91·969	210 ±	0·5 ±	7–9½
				92·895	200·1		
				92·953	199·2		
				92·956	200·1	1·09	
3	A G C 1690	1 39	55 22	92·977	179·3	1·0 ±	8–8½
4	A G C 3516	3 10	47 34	92·008	248·0	...	8–8
				92·036	248·1	0·93	
				92·038	249·3	0·97	
5	A G C 4117	3 39	48 33	92·036	187·7	1·81	7–12
				92·038	188·4	1·67	
				92·049	188·4	1·81	
6	St. 1898	4 23	53 20	92·038	98·8	0·88	7–9
				92·055	98·0	0·74	
7	Z Puppis	6 27	50 10	93·088	262·9	...	6–6
	St. 3044	...	...	93·104	265·4	0·68	
				93·162	267·2	0·68	
8	St. 4451	8 29	52 52	92·266	303·1	0·5 ±	6½–7½
				92·276	298·9		
				92·320	303·5	0·43	
9	Z C 3683	8 46	63 27	93·156	2·4	1·02	8–9
				93·194	2·7	0·91	
10	A G C 16725	12 10	35 40	91·342	244 ±	1·5 ±	7½–8½
				91·359	244·1		
11	St. 8614	15 46	60 27	91·548	95·3	0·56	6½–8½
				91·553	98·9		
				93·493	93·9	1·00	
12	Z C 2139	16 33	47 51	93·586	178·1	1·02	8–8½
				93·608	178·2	0·98	
13	Z C 309	18 6	35 14	91·665	43·7	1·5 ±	9–10
14	St. 12307	23 45	52 16	91·934	70·4	0·90	7–7½

Observatory, Sydney:
1893 *October* 20.

Observations of Brooks' Comet (c 1893), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to one another, and each inclined 45° to the parallel of declination.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

Greenwich Mean Solar Time.					Observer.	☄ − ✱ R.A.	Log Factor of Parallax.	Corr. for Refraction.	☄ − ✱ N.P.D.	Log Factor of Parallax.	Corr. for Refraction.	No. of Comps.	Appt. R.A. of ☄.	Appt. N.P.D. of ✱.	Comp. Star.
1893.	d	h	m	s		m s		s	′ ″		″		h m s	° ′ ″	
Nov.	9	15	35	20	A.C.	+ 5 49·87	9·6311	0·00	− 1 43·8	0·7785	0·0	1	12 59 13·05	59 22 43·5	*a*
	9	15	35	20	„	+ 4 52·17	9·6311	0·00	+ 0 38·7	0·7785	0·0	1	12 59 13·22	59 22 38·0	*b*
	26	16	49	6	B.	− 0 19·04	9·7050	+0·01	− 7 53·4	0·4864	−0·1	3	...	...	*c*
	26	16	53	50	„	− 0 50·73	9·7013	−0·01	+ 7 16·2	0·4751	+0·1	2	...	...	*d*
Dec.	1	11	35	6	„	+ 0 23·15	9·5359	0·00	− 0 45·7	0·8918	−0·1	3	14 3 59·65	36 43 58·1	*e*
	1	11	42	29	A.C.	+ 0 23·12	9·5559	0·00	− 1 17·7	0·8872	−0·1	3	14 3 59·62	36 43 25·3	*f*
	2	14	59	47	B	+5 12·09	9·8010	0·00	− 2 17·3	0·6440	−0·1	2	...	...	*f*
	2	15	0	28		+0 45·02	9·8012	−0·01	+ 9 14·7	0·6428	+0·1	3	14 9 13·26	35 25 14·0	*g*
	4	11	35	1	„	−0 16·23	9·5589	−0·02	−10 55·0	0·8827	−1·4	3	14 18 28·47	33 16 54·7	*h*
	4	11	36	15	„	−2 25·89	9·5646	−0·01	− 5 43·5	0·8821	−0·8	4	14 18 29·42	33 16 53·4	*i*
	4	11	51	54	„	+4 29·95	9·6099	+0·01	+10 21·6	0·8722	+1·2	2	...	...	*k*

Notes.

Nov. 9.—Distinct straight tail in south preceding direction.
Nov. 26.—Comet extremely faint; very diffused; sky bright; observations not very accurate.
Dec. 2.—Comet extremely faint; near a pair of faint stars.
Dec. 4.—Comet very faint; hardly any condensation; extremely difficult to observe; near a faint star.

The initials A.C. and B. are those of Mr. Crommelin and Mr. Bryant respectively.

Assumed Mean Places of the Comparison Stars.

	Comparison Star.	Assumed R.A., 1893·0.	Assumed N.P.D., 1893·0.	Authority.
		h m s	° ′ ″	
a	W.B. (2) XII. 1025, 1027	12 53 21·96	59 24 9·8	Leiden Ast. Gesell. Zones, 43, 44.
b	W.B. (2) XII. 1041, 1042	12 54 19·84	59 21 41·8	,, ,, ,, ,,
c	B.D. + 47°, 2095	13 45 3	42 17·7	Bonn Observations, vol. v.
d	Anonymous	13 45 36	42 2	Difference from Star *c*.
e	B.D. + 53°, 1689	14 3 35·84	36 44 16·8	Cambridge, U.S., Ast. Gesell. Catalogue.
f	B.D. + 54°, 1648	14 3 55	35 26·4	Bonn Observations, vol. v.
g	B.D. + 54°, 1653	14 8 27·70	35 15 31·8	Cambridge, U.S., Ast. Gesell. Catalogue.
h	B.D. + 56°, 1728	14 18 44·35	33 27 23·4	Helsingfors Gotha ,, ,, ,,
i	B.D. + 56°, 1732	14 20 54·99	33 22 10·1	,, ,, ,, ,, ,,
k	B.D. + 57°, 1500	14 14 0	33 7·6	Bonn Observations, vol. v.

Royal Observatory, Greenwich:
1893 *December* 7.

Erratum in Hansen's "Tables de la Lune." By A. M. W. Downing, M.A., D.Sc.

On page 406, 1900, Arg. 19,
for 14.44231
read 14.44213.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. JANUARY 12, 1894. No. 3

Lieut.-General TENNANT, C.I.E., R.E., F.R.S., Vice-President, in the Chair.

William Briggs, B.A., LL.B., F.C.S., Burlington House, Cambridge;
John Harrison Buckley, 70 Tower Street, Leicester;
John Evershed, jun., Kenley, Surrey;
Joshua Jukes, 43 High Street, Smethwick, near Birmingham;
Henry Alfred Lenehan, Astronomical Assistant, Government Observatory, Sydney, Australia;
Armin Otto Leuschner, A.B., Assistant Professor of Astronomy in the University of California, San Francisco;
Henry MacEwen, 5 Cathkin Terrace, Mount Florida, Glasgow;
Rev. David Powell Richards, B.A., Chaplain and Naval Instructor to H.M.S. *Canada*, Bermuda;
Richard Pickering Sellors, B.A., Astronomical Observer, Government Observatory, Sydney, Australia;
Max Wolf, Ph.D., Professor of Astronomy in the University, Heidelberg, Germany,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Augustin Stanislaus Ghosh, 28 Convent Road, Calcutta (proposed by A. C. D. Crommelin);
Lieutenant William H. F. Montanaro, R.N., H.M.S. *Canada*, Bermuda (proposed by Sir Josiah Rees);

Walter A. Post, Civil Engineer, Newport News, Virginia, U.S.A. (proposed by S. W. Burnham);
Alexander William Roberts, Mathematical Master, Alice, Lovedale, Cape Colony (proposed by David Gill).

Sixty-eight presents were announced as having been received since the last meeting, including, amongst others —

Bulletin du Comité International pour l'exécution photographique de la Carte du Ciel, tome ii., fasc. 2, presented by the French Academy; Ch. Dufour, La Scintillation des Etoiles, presented by the Author; German Transit of *Venus* Commission, Bericht über die deutschen Beobachtungen, herausgegeben von A. Auwers, Band V., presented by the Commission; F. Tisserand, Traité de Mécanique Céleste, tome iii., presented by the Author; Webb's Celestial Objects, new edition, vol. i., by the Rev. T. E. Espin, presented by the Publishers; Original negatives of *Jupiter*, and copies of Mr. Schaeberle's photographs of the Corona of 1893 April, presented by the Lick Observatory.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1891, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lii., p. 24, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1891; and Table II. gives the same particulars for the entire year 1891, and for the two preceding years, for the sake of comparison. The areas are given in two forms. First, projected areas, that is to say, as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1891 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results for 1889 and 1890 being added as in the case of

Table II. Tables II. and IV. are thus in continuation of the similar tables on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

It will be noticed that the results for 1889 are also given in Table IV. in several parts. That year being the year of minimum, the spots during the earlier months were situated close to the equator, but after the minimum was passed, and the new cycle had commenced, spots appeared in much higher latitudes. No spots at all were seen either in the northern or southern hemisphere in the zones of mid-latitude; two zones, 8° broad, and having their centres in lat. 15° north and south respectively, being entirely barren. Up till June 28 not a single spot with a latitude over 11° was observed; on June 29 and 30 a small spot was seen in south lat. 40°. A second high latitude spot was seen on July 26, and they then began to become more numerous. On September 4 a small low latitude spot was seen for the last time, and for three months all the spots observed were in high latitudes. The year has therefore been divided into three periods: January 1 to June 28, when all the spots were in low latitudes; June 29 to September 4, when spots were seen both in high and low latitudes; and September 5 to December 31, when activity was almost entirely confined to the high latitude zones. And in each period the high and low latitude spots have been exhibited separately, the broad barren zone above alluded to marking off the two districts most unmistakably.

Table I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Projected. Whole Spots.	Projected. Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected for Foreshortening. Whole Spots.	Corrected for Foreshortening. Faculæ.
	1890.							
498	Dec. 21·75	27	6·2	41·7	368	6·7	58·3	689
	1891.							
499	Jan. 18·09	26	66·1	385	601	41·7	240	693
500	Feb. 14·43	27	67·0	353	641	50·9	270	714
501	Mar. 13·76	27	61·3	278	731	46·7	225	840
502	Apr. 10·05	27	72·9	444	760	56·9	370	888
503	May 7·30	27	142	825	1276	94·8	596	1256
504	June 3·51	28	131	865	1824	88·3	610	1600
505	June 30·71	27	246	1458	2183	183	1133	2336
506	July 27·91	27	92·4	670	1804	71·3	578	1917
507	Aug. 24·14	28	243	1608	1227	170	1207	1415
508	Sept. 20·41	27	159	1044	1990	117	823	2096
509	Oct. 17·69	27	67·3	422	1577	44·6	288	1710
510	Nov. 13·99	28	140	807	1513	95·4	593	1685
511	Dec. 11·31	27	183	1141	1792	129	864	1915

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Projected. Whole Spots.	Corrected for Foreshortening. Faculæ.	Umbræ.	Whole Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412

The rotations in Table I. and Table III. are numbered in continuance of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	1890. d			°		°	°	°
498	Dec. 21·75	27	9·7	23·22	48·6	26·33	−18·11	25·81
	1891.							
499	Jan. 18·09	26	105	18·86	135	26·86	− 6·78	23·35
500	Feb. 14·43	27	242	19·17	28	22·66	+14·84	19·53
501	Mar. 13·76	27	221	19·73	3·5	25·38	+19·02	19·81
502	Apr. 10·05	27	149	22·36	221	20·45	− 3·20	21·22
503	May 7·30	27	316	18·20	280	20·57	+ 0·01	19·31
504	June 3·51	28	486	18·40	124	19·32	+10·72	18·58
505	June 30·71	27	1049	19·67	84·4	20·87	+16·65	19·76
506	July 27·91	27	337	21·09	240	18·38	+ 4·66	19·96
507	Aug. 24·14	28	1175	21·47	32·3	22·69	+20·29	21·51
508	Sept. 20·41	27	400	20·78	423	18·64	+ 0·51	19·68
509	Oct. 17·69	27	284	18·29	3·9	19·22	+17·79	18·30
510	Nov. 13·99	28	219	19·48	374	18·78	− 4·67	19·04
511	Dec. 11·31	27	567	25·09	297	18·46	+10·12	22·81

The chief features of the Sun-spot record for 1891 as brought out by the preceding tables are:—(1) The great increase in the mean daily area of umbræ, whole spots and faculæ; an increase which is proportionately about the same for the umbræ and whole spots, but not quite so strongly marked for the faculæ. The ratios which the areas for 1891 bear to those of 1890 are 5·56 and 5·72 respectively in the two former cases, in the last case 4·65.

The minimum, therefore, has been evidently passed, and the new cycle is rapidly progressing towards full vigour.

(2) The high latitude occupied by the spots. The overwhelming majority have shown a latitude of more than 14°, less than 3 per cent. of the total spotted area lying nearer the equator than 13°·5, whilst the mean distance from the equator of all spots has been 20° 31′. This, though higher than the value for 1880, the corresponding year of the last cycle, was lower than that for 1890, and thus affords a second indication that the new cycle is in full action.

(3) A third feature is the predominance of spots in the northern hemisphere. If the precedent of the last cycle hold good, this also is typical of the earlier days of a new cycle. On the whole, therefore, the record for 1891 would indicate not merely that the minimum was past, and the rise towards maximum in full force, but also, from both the areas and latitude being greater than in 1880, and from the predominance of the northern hemisphere being more pronounced, that the approaching maximum will be more strongly marked than was the case with that of 1883.

TABLE IV.

Period.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1889. Low Spots.							
Jan. 1–June 28	177	7·9	5°·36	45·5	5°·44	− 3°·85	5°·43
June 29–Sept. 4	65	2·9	2·69	133·0	7·26	− 7·05	7·16
Sept. 5–Dec. 31	118	0	...	5·0	8·73	− 8·73	8·73
1889. High Spots.							
Jan. 1–June 28	177	0	...	0	...	...	...
June 29–Sept. 4	65	0	...	84·1	21·96	−21·96	21·96
Sept. 5–Dec. 31	118	1·8	23·94	30·0	22·95	−20·29	23·01
All Spots.							
1889	360	5·0	7·26	73·0	11·90	−10·68	11·61
1890	361	53·1	22·20	46·3	21·75	+ 1·73	21·99
1891	363	401	20·49	169	19·91	+ 8·52	20·31

On the Dark Poles and Bright Equatorial Belt of the First Satellite of Jupiter. By E. E. Barnard, M.A.

It will, perhaps, be remembered that on 1890 September 8, while observing the transit of the first satellite of *Jupiter* with the 12-inch equatorial, the satellite appeared as a dusky elongated spot projected on a bright region of *Jupiter*. With a high power it appeared distinctly double, on a line nearly vertical to the belts of *Jupiter*. I called Mr. Burnham's attention to it, and we both saw it thus for upwards of half an hour. Subsequently it was seen several times when crossing a dark portion of the planet as a bright, very elongated spot, but the elongation in these cases was nearly parallel to the belts of *Jupiter*. Yet when closely examined on the sky it always appeared perfectly round.

An account of these observations will be found in *Monthly Notices*, vol. li., No. 9. To explain these singular peculiarities I at that time offered two theories: the first of these was that the satellite was itself possibly double. This idea has long since been abandoned because of its improbability. The second theory supposed the satellite to be surrounded with a white equatorial belt, and that its poles were dark or dusky, and that it rotated on an axis nearly perpendicular to its orbit. If such were the case, when the satellite crossed a bright portion of the planet the white belt would cut it apparently in two, as it would be equal in brightness to the surface of *Jupiter*, and thus leave the two dark polar caps as two separate spots nearly perpendicular to the belts of *Jupiter*, and would thus give the observed appearance of duplicity.

If, however, the satellite should happen to be projected on a dark belt, then the dark poles would merge into the surface of *Jupiter*, and the white equatorial belt alone would be visible as an elongated white spot nearly parallel to the belts of *Jupiter*.

It was not until this year (1893) that an opportunity occurred to settle this question with the 36-inch.

On September 25 last the transit of this satellite was watched with the great telescope. It first appeared as an elongated white spot, east and west, when over the dusky region near the planet's limb, and later it appeared as two dusky spots in a line north and south, exactly as it appeared in the 12-inch 1890 September 8. But during moments of good definition it was seen distinctly as a small round disc, dusky at the poles, and with a white belt between them.

On November 11 it was again observed under nearly similar conditions, and presented the same phenomena.

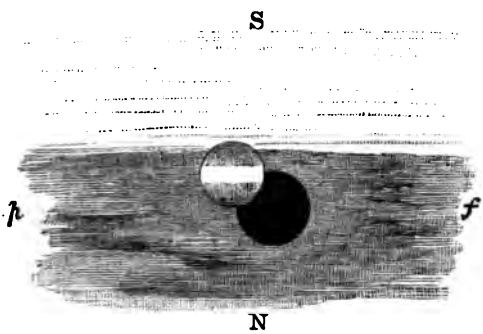
The best view of these dark polar caps and bright belt was had on November 19, with a power of 1,000 diameters on the great telescope, and almost perfect seeing.

At this transit the satellite partly obscured its own shadow on the south preceding side, and was partly projected on the southern edge of the south equatorial belt, and partly on the bright region beyond.

With the fine seeing the satellite presented a beautiful appearance. It stood out in bold relief like a little globe. The polar caps were heavily marked and quite dark, while the bright belt was very conspicuous.

The observation was perfectly satisfactory, and the second theory had become a fact.

I send a careful drawing of the appearance of the satellite on this date, which will give a good idea of the phenomenon. The shadow was larger than the satellite.



Transit of Satellite I., 1893 Nov. 19 ; 36-in. Refractor.

We have here established the discovery made 1890 September 8 with the 12-inch telescope, that this little attendant on *Jupiter* has distinct polar caps that are dusky like those of *Jupiter*, and that it has a bright equatorial belt, as bright as the brightest portion of *Jupiter's* surface. The conclusion is uncontestable, therefore, that the satellite also rotates on an axis nearly perpendicular to its orbit, as *Jupiter* itself does.

From the fact that the bright belt is not always exactly parallel to those on *Jupiter*, and the line between the polar caps is not always exactly perpendicular to the belts of *Jupiter*, there must be a slight inclination of the axis of rotation of the satellite. From the fact also that the south cap is sometimes apparently a little smaller than the northern one, its axis is probably tipped away from us at its southern end. It is also probably tilted towards the west by a few degrees. From peculiarities in the appearance of the belt, it is probable that the period of rotation on this axis is not coincident with the satellite's period of revolution about *Jupiter*.

I have data in my hands now that will after a few more observations, perhaps, settle the inclination of the axis, and probably give us the period of rotation.

I think the presence of these dusky poles and bright belt would rather imply that this satellite at least is in a physical condition not vastly different from that of *Jupiter* itself.

Mount Hamilton, California:
1893 *November* 27.

Photograph of the Nebulæ H I 56 *and* 57 *Leonis.*

By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebulæ H I 56 and 57 *Leonis*, R.A. $9^h\ 26^m$, Decl. 21° 59′ north, was taken with the 20-inch reflector on 1893, April 4, with exposure of the plate during 4 hours, and is enlarged to the scale of 1 millimètre to 24 seconds of arc.

The nebulæ are Nos. 2903 and 2905 in the *New General Catalogue*, and 1861–1863 in the *General Catalogue*.

No. 1861 is described by Sir J. Herschel (*General Catalogue*, p. 79) as considerably bright, very large, extended, gradually much brighter in the middle, resolved; *s. p.* of 2. No. 1863 is described as very faint, considerably large, round, pretty suddenly brighter in the middle, resolved; *n. f.* of 2. These nebulæ are figured in the *Phil. Trans.*, 1833, Pl. XV., fig. 70, p. 495, but the drawing does not at all resemble the photograph.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, pp. 76, 77, and Pl. III., fig. 5, 1851) gives the results of thirty observations of the nebula made between the years 1846 and 1878. A drawing is also given in the *Phil. Trans.* for 1850, Pl. XXXVI., fig. 3. The drawing, which was made in the year 1851, is in its outlines very fairly in agreement with the photograph, but of course the details of the extensions and condensations of the nebulous matter are not as shown on the photograph.

The photograph shows the nebula to be a symmetrical spiral, with great extensions of very faint nebulosity on the north and south sides. The nucleus is stellar in the centre of the convolutions of the spiral, which, owing to perspective effects, are elongated so as to appear of an elliptical form in nearly north and south directions. The convolutions of the spirals are broken up into nebulous star-like patches with faint nebulosity between them. On the negative the faint nebulosity is seen to extend further to the north and to the south than is shown on the print which is now presented.

The nebula H II 260 is also shown on the photograph $2^m\ 45^s$ *following*, and 13 minutes of arc *north*. It has a stellar nucleus resembling two faint stars surrounded by very faint nebulous rings.

It will be observed that the stars in the region of these nebulæ are pretty numerous.

Photograph of the Nebula H I 200 *Leonis Minoris.*

By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebula H I 200 *Leonis Minoris*, R.A. $8^h\ 46^m$, Decl. 33° 49′ north, was taken on 1893, March 19, with exposure of the plate during three hours. Scale: 1 millimètre = 24 seconds arc.

The nebula is No. 2683 in the *New General Catalogue*, and 1713 in the *General Catalogue*, and is described by Sir J. Herschel as very bright, very large, very much extended in the direction of 40° 9′, gradually much brighter in the middle.

Lord Rosse, in the *Observations of Nebulæ and Clusters of Stars*, p. 70, gives the results of sixteen observations of the nebula made between the years 1851 and 1876. He describes it as a very large lenticular ray, slightly concave on the *n. p.* side, gradually very much brighter in the middle, perhaps 10′ long, and he suspected the existence of very faint streaks and lanes on each side parallel to the ray.

The photograph shows the nebula with a strong stellar nucleus in the midst of dense nebulosity, which is of a flocculent character, and it is doubtless similar in form to the great nebula in *Andromeda*, but apparently very much smaller in size, and seen more edgewise; the rings are therefore not visible, though their existence is very probable. The nebula measures on the photograph about six and a half minutes of arc in length, and is in a region of the sky which is not exceptionally studded with stars; they are mostly faint, and are shown to about the 16th magnitude.

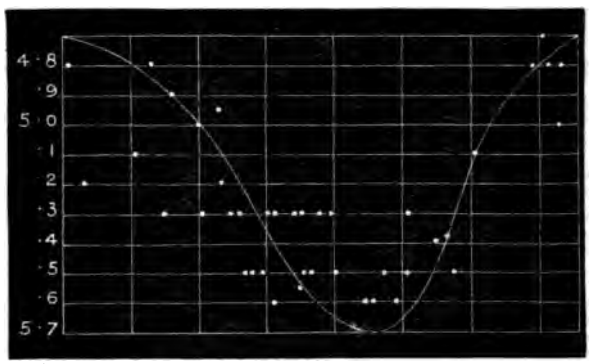
Observations of the Variable Stars W and X Sagittarii.

By Lieut.-Colonel E. E. Markwick.

W Sagittarii.—This star can be easily compared with No. 14 of *Sagittarius* in the *Uranometria Argentina*, 5·4 m., which is well situated for the purpose, as the binocular shows them nicely in the same field. The following observations were made with a binocular magnifying about five times. The observed magnitudes in the *U. A.* scale were plotted on ruled paper, in which the horizontal lines represent brightness, and the vertical ones the dates. The maxima, calculated from the data given in Mr. S. C. Chandler's valuable *Second Catalogue of Variable Stars*, viz. Epoch 1866 September 4 + 7·59460 E, were then marked by ordinates. A typical curve based on the same period and (M − *m*), the interval from minimum to next following maximum, = 3·00 days, was drawn on tracing-paper, and the differences

O—C read off on a scale of equal parts. Finally, the whole of the observations were plotted on the typical curve.

A diagram on these principles is attached. It will be seen that the dots have a curious tendency to range themselves in horizontal lines.



W Sagittarii. Typical Light-curve, with summarised Observations.

This *may* be due to the fact that the determinations of brightness were nearly all in tenths of a magnitude, and hence the dots *must* usually fall on some of the lines. But why they should cluster on the lines 5·4 and 5·6 I cannot say. It might be due either to systematic errors in determining the brightness, or to a real suspension or delay in the diminution of the star's brightness when it arrives near those magnitudes.

According to my estimates, the star varies between 4·8 m. and 5·7 m. Considering the large amount of probable error there is in estimating brightness, the observations seem to confirm the period well enough, those of July 31, August 31, and September 30 falling very close to the maximum lines. The hour of observation is only approximate to within five minutes, and is in G.M.T.

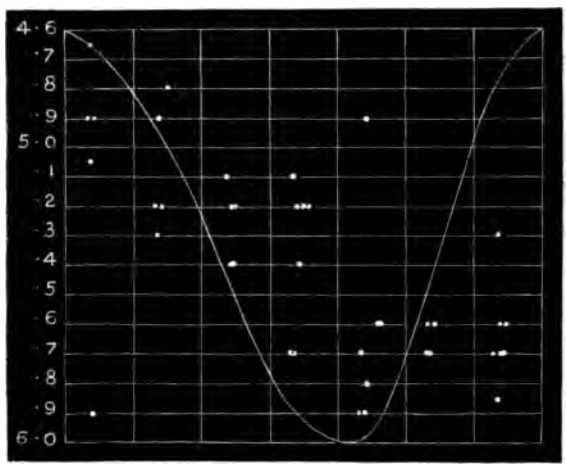
Both in the case of this and the following star I was quite ignorant, when making the observations, as to when the maxima were due, as I had not then calculated the dates, so the observations are free from any bias which such a knowledge might have produced.

W Sagittarii.

Date.		Observed brightness.	O−C *d*	Remarks.
1893	h m			
July 19	10 41	5·6	−0·3	
20	11 36	5·4	+1·2	
22	10 19	5·6	+0·6	
29	8 40	5·4	−0·7	Moonlight.
31	9 36	4·8	−0·5	Naked eye est.
31	11 35	4·9	+0·2	Binocular.

Date. 1893.	h	m	Observed brightness.	O−C *d*	Remarks.
Aug. 3	11	6	5·4	−0·3	
4	9	11	5·4	+0·3	
4	10	6	5·6	−0·1	
5	9	26	5·7	−0·6	
10	9	6	5·1	0·0	
10	10	51	5·4	−0·8	
11	8	46	5·6	−0·4	
11	10	16	5·4	+0·2	
12	9	0	5·6	+0·6	
15	9	21	4·9	−0·1	Clouds about.
16	9	5	5·3	−2·2	
17	9	36	4·9	+0·3	
18	9	56	5·3	−0·3	Moon.
20	9	36	5·4	−1·4	Strong Moon.
27	8	11	5·6	+0·3	Clouds and Moon.
28	9	9	5·6	−0·8	Moon.
31	9	6	4·9	+0·7	
Sept. 1	9	14	5·2	−1·2	
3	10	9	5·4	+0·3	
5	9	26	5·6	−0·4	Poor night.
9	8	32	5·4	−1·3	
10	7	56	5·4	−0·4	
11	7	36	5·4	+0·6	
11	9	6	5·65	0·0	
12	9	11	5·7	−0·6	
13	9	11	5·5	−0·1	
19	8	46	5·4	+1·1	
20	7	38	5·7	−0·3	Moonlight.
25	8	32	5·05	+0·6	
30	7	21	5·1	+1·0	On and after this date star getting low and comparison difficult.
30	8	47	4·9	+0·4	
Oct. 1	8	11	5·2	+2·2	
2	7	35	5·0	0·0	
3	8	46	5·6	−0·6	
6	7	55	5·5	0·0	
11	7	41	5·7	−0·6	
14	7	30	5·2	0·0	

X Sagittarii.—Observations of this star are not satisfactory, as it is difficult, to my eye, to determine its brightness with accuracy. I have generally compared it with 4 *Sagittarii*, but when verging towards the west 4 is almost perpendicular above *X*, and atmospheric absorption must then affect the comparison of the two stars, as they are separated by an interval of 5° or so. This applies particularly to observations on and after September 25, which are given for what they are worth. According to my judgment, this star seems to vary between 4·6 and 6·0 mags., or thereabout, in the *U. A.* scale.



X Sagittarii. Typical Light-curve, with summarised Observations.

The maxima of the star, calculated from the period given in Chandler's Catalogue, happen, in 1893, very near midnight, every seven days, beginning, for my observations, on July 25. Hence the observations of July 31, August 15, 28, September 5, 11, 19, and October 2, being close to the maximum point, ought to be high in the scale—certainly above 5 m. But only two of these, viz. August 15 and September 12, show the star above 5·0 m., while those of September 11 and October 3 show it actually of nearly minimum brightness! I can only account for these discrepancies by errors in estimation of the brightness of the star. Curiously enough, the discs in this case when plotted on the curve have a tendency to run in *vertical* groups, as shown in annexed diagram. The observations were made in the same way as those of *W Sagittarii*, and are as follow :—

X Sagittarii.

Date. 1893.	h	m	Observed brightness.	O−C *d*	Remarks.
July 19	10	36	4·8	+0·5	
20	11	36	5·2	+0·6	
22	10	19	4·9	−1·6	Compared with 14 *U.A. Sagittarii.*
29	8	40	5·7	−0·6	
31	9	36	5·3	+0·7	Naked-eye view.
31	11	35	5·6	+1·2	
Aug. 3	11	6	5·4	+0·2	
4	9	11	5·4	+1·1	
4	10	6	5·2	+1·5	
5	9	26	5·6	−0·7	
10	10	51	5·2	+0·6	Observation hurried.
11	8	36	5·1	+1·7	
11	10	16	5·2	+1·5	
12	9	0	5·6	−0·7	
15	9	21	4·9	−0·8	
16	9	5	5·3	−0·7	
17	9	36	5·1	+0·7	Clouds.
18	9	56	5·7	+0·6	Moon.
20	9	36	5·7	+0·4	Moon and Clouds about.
28	9	9	5·6	+1·4	Moon.
31	9	6	5·4	+0·1	
Sept. 1	9	31	5·2	+1·5	
3	10	11	5·6	+0·3	
5	9	26	5·05	−1·2	Poor night.
9	8	34	5·8	−0·4	
10	7	56	5·6	+0·2	
11	7	36	5·85	+1·6	
11	9	6	5·7	+1·4	
12	9	11	4·65	0·0	
13	9	11	5·2	−0·5	
19	8	46	4·9	−0·8	Moon.
20	7	38	5·2	−0·6	
25	8	32	5·7	+1·3	Observation vague.
30	7	21	5·9	−0·4	
Oct. 1	8	11	5·7	+0·4	
2	7	37	5·7	+1·3	
3	8	46	5·9	−3·0	
6	7	55	5·7	+0·5	
11	7	41	4·9	+0·1	
14	7	30	5·9	−0·1	

Influence of the Full Moon on the Weather.

By the Rev. S. J. Johnson, M.A.

The theory that the Moon affects the weather has been long exploded, but the solitary observable effect of the Moon upon our atmosphere was believed by Sir J. Herschel to be exhibited in the disappearance of cloud under the full Moon, and this he attributed to the heat radiated from her surface. Humboldt speaks of this idea as well known to the pilots and seamen of Spanish America. M. Arago also spoke of more rain falling at the time of new Moon than at the time of full Moon. With a view of ascertaining whether clouds are more dispersed at the period of full Moon than previously, I have noticed the state of the sky at moonrise and at midnight on the day of full Moon for the past fifteen years, with the result that there is no foundation for the theory referred to.

Column 1 indicates sky similar when full Moon rose and at midnight.
2 = Clearer about midnight than at moonrise.
3 = More overcast about midnight.

Years.	1	2	3
1879	10 times	2 times	1 time
1880	6 „	4 „	2 times
1881	8 „	2 „	2 „
1882	5 „	4 „	4 „
1883	8 „	1 time	3 „
1884	9 „	2 times	1 time
1885	8 „	4 „	1 „
1886	7 „	3 „	2 times
1887	10 „	1 time	2 „
1888	11 „	0 „	1 time
1889	7 „	3 times	2 times
1890	10 „	2 „	1 time
1891	10 „	2 „	0 „
1892	7 „	3 „	2 times
1893	10 „	0 „	3 „
Totals	126	33	27

Melplash Vicarage, Bridport.

Observations of Brooks' Comet (c 1893), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to one another, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.				Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1893.	d	h	m s		m s	s		′ ″	″			h m s	° ′ ″	
Dec.	7	6	3 23	B.	+3 6·06	−0·01	9·7558	−11 0·6	−0·7	0·8106	2	...	...	*a*
	7	6	16 8	,,	+2 7·64	0·00	9·7346	+16 30·9	+1·2	0·8241	3	14 34 12·87	30 7 30·4	*b*
	7	6	18 33	,,	+2 13·15	0·00	9·7304	+14 11·8	+1·1	0·8266	2	14 34 12·81	30 7 15·1	*c*
	9	8	42 1	H.	+0 44·94	0·00	9·2223	+ 2 29·6	+0·4	0·9015	4	14 47 59·40	27 46 50·3	*d*
	9	11	54 20	,,	+1 45·35	0·00	9·6602	− 5 49·6	−0·6	0·8566	3	14 48 59·81	27 38 30·1	*d*
	15	13	7 19	B.	+4 14·00	0·00	9·8548	+ 0 27·7	0·0	0·7784	6	15 41 12·49	21 26 7·6	*e*
	15	13	7 19	,,	+2 53·00	+0·01	9·8548	− 3 38·3	−0·2	0·7784	6	15 41 11·99	21 26 10·1	*f*
	15	14	10 37	,,	−1 33·91	−0·02	9·9503	+ 4 13·2	+0·2	0·6914	5	15 41 42·21	21 23 39·6	*g*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires, and for the motion of the comet.

December 15.—The comet was brighter and more condensed than on December 7. Observations much interfered with by fleecy clouds.

The initials H. and B. are those of Mr. Hollis and Mr. Bryant respectively.

Comparison Stars.

	Star's Name.	R.A. 1893·0.	N.P.D. 1893·0.	Authority.
		h m s	° ′ ″	
a	Anonymous	14 31 7	30 18·6	Difference from star *b*.
b	B.D. + 60°; 1552	14 32 5·23	29 50 30·0	Helsingfors Gotha Ast. Gesell. Catalogue.
c	B.D. + 60°, 1551	14 31 59·66	29 52 33·9	,, ,, ,,
d	B.D. + 62°; 1370	14 47 14·85	27 43 52·1	,, ,, ,,
e	B.D. + 68°; 844	15 37 0·62	21 25 13·8	Christiania Ast. Gesell. Catalogue.
f	B.D. + 68°; 846	15 38 21·12	21 29 22·6	,, ,, ,,
g	B.D. + 68°; 849	15 43 18·46	21 19 0·8	,, ,, ,,

Royal Observatory, Greenwich:
1894 *January* 9.

Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the Year 1893.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day.	Phenomenon.	Telescope.	Power.	Moon's limb.	Mean Solar Time of Observation. h m s	Observer.
1893 Feb. 26	Disapp. *c* Geminorum	Merz. Refractor	418	Dark	9 58 35·05	L.
Apr. 18	,, 32 Tauri	Astrographic Equat.	225	,,	9 6 59·60	C. D.
18	,, 32 Tauri	E. Equat.	55	,,	9 7 0·30	A. C.
18 (*a*)	,, B.D. + 22° No. 602	Astrographic Equat.	225	,,	8 57 32·95	C. D.
18 (*b*)	,, B.D. + 22° No. 606	,,	,,	,,	9 7 46·77	,,
19 (*c*)	,, B.D. + 25° No. 762	Altaz.	100	,,	8 13 (3·24)	H.
19	,, B.D. + 25° No. 762	Astrographic Equat.	225	,,	8 13 13·76	C. D.
19 (*d*)	,, W.B. (2) IV. 1,144	Altaz.	100	,,	8 39 35·08	H.
19	,, W.B. (2) IV. 1,144	Astrographic Equat.	120	,,	8 39 34·87	C. D.
19 (*e*)	,, W.B. (2) IV. 1,142	Altaz.	100	,,	8 43 46·88	H.
19	,, W.B. (2) IV. 1,142	Astrographic Equat.	120	,,	8 43 48·58	C. D.
20	,, B.D. + 27° No. 963 (1st *)	,,	,,	,,	7 56 11·02	,,
20 (*f*)	,, B.D. + 27° No. 964	,,	,,	,,	8 3 9·57	,,
20	,, B.D. + 27° No. 966	Merz. Refractor	418	,,	8 9 1·24	L.

Day.	Phenomenon.	Telescope.	Power.	Moon's limb.	Mean Solar Time of Observation. h m s	Observer.
1893 Apr. 20	Disapp. B.D. + 27° No. 966	Astrographic Equat.	120	Dark	8 9 0·93	C. D.
20	,, B.D. + 27° No. 966	3-in. Finder of Merz. Refractor	50	,,	8 9 1·02	D. E.
20	,, B.D. + 27° No. 994	E. Equat.	70	,,	9 43 5·55	C. D.
21	,, 47 Geminorum	$2\frac{1}{3}$-in. Finder of E. Equat.	24	,,	9 17 35·21	H. T.
21	,, 47 Geminorum	Altaz.	100	,,	9 17 35·60	B.
21	,, 47 Geminorum	E. Equat.	...	,,	9 17 35·31	J.
21 (*g*)	,, W.B. (2) VII. 318	Altaz.	100	,,	12 39 9·00	B.
22	,, λ Cancri	E. Equat.	70	,,	12 34 53·22	A. C.
May 6	Reapp. *b* Sagittarii	,,	,,	,,	16 16 17·51	H.
18	Disapp. B.D. + 27° No. 1,226	Astrographic Equat.	120	,,	8 53 22·80	C. D.
18	,, B.D. + 27° No. 1,229	,,	,,	,,	9 8 20·74	,,
18	,, W.B. (2) VI. 1,192–3	,,	,,	,,	9 21 46·77	,,
18	,, B.D. + 27° No. 1,237	,,	,,	,,	9 31 44·53	,,
27 (*h*)	,, B.D. − 15° No. 3,862	,,	,,	,,	9 37 39·44	,,
June 20	,, B.D. + 2° No. 2,499	,,	225	,,	10 13 27·71	H. F.
20	,, B.D. + 2° No. 2,499	Altaz.	60	,,	10 13 27·98	C. D.
July 9 (*i*)	,, 32 Tauri	,,	100	Bright	13 37 14·84	B.
9	Reapp. 32 Tauri	,,	,,	Dark	14 27 29·93	,,
9	,, 32 Tauri	Astrographic Equat.	225	,,	14 27 29·78	A. E.

Day.	Phenomenon.	Telescope.	Power.	Moon's limb.	Mean Solar Time of Observation. h m s	Observer.
1893 July 30	Reapp. 56 Aquarii	Astrographic Equat.	225	Dark	10 25 18·58	H. F.
Sept. 26 (*j*)	,, *e* Piscium	,,	,,	,,	7 11 1·47	,,
Oct. 19	Disapp. 37 Capricorni	E. Equat.	55	,,	9 3 22·84	B.
19	,, 38 Capricorni	Astrographic Equat.	225	,,	9 5 10·26	C. D.
25 (*k*)	,, 40 Arietis	E. Equat.	55	Bright	15 8 44·38	C. M.
30 (*l*)	Reapp. ω^2 Cancri	Altaz.	100	Dark	11 44 29·72	B.
30	,, ω^2 Cancri	E. Equat.	55	,,	11 44 29·47	C. D.
Nov. 22	Disapp. δ Arietis	,,	,,	,,	10 19 (36·54)	L.
22 (*m*)	,, δ Arietis	Astrographic Equat.	·225	,,	10 19 46·80	H. F.
22	,, δ Arietis	Altaz.	100	,,	10 19 45·89	D. E.
Dec. 14	,, B.D. − 14° No. 6,301	Astrographic Equat.	225	,,	5 42 29·97	C. D.

Notes.

(*a*) Limb distinctly seen. (*b*) Difficult observation.
(*c*) The dark limb was quite visible and the star disappeared at above time, but there was a momentary flash about 10 secs. later, as though the star was seen through the limb.
(*d*) The star appeared to disappear behind limb at $10^h\ 31^m\ 48{\cdot}5^s$, and was then repeatedly seen again as though through limb; it was last seen at above time.
(*e*) There was a cloud over the moon which had previously obscured the star; this is not considered a good observation; the star was difficult to see. (*f*) Poor observation; very faint; cloudy. (*g*) A very difficult observation.
(*h*) Not considered a good observation. (*i*) Not considered a good observation. (*j*) Limb nearly full, so probably a little late.
(*k*) Disappeared in blue rim of moon. (*l*) A rough observation. (*m*) Bright and instantaneous.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m	Observer.
1893 Jan. 2	III.	Tr. Ing. First contact	E. Equat.	200	8 35 53		A. C.
2	III.	Bisection	,,	,,	8 40 8	8 39	,,
2	III.	Last contact	,,	,,	8 43 12		,,
2	III. (*a*)	Tr. Ing. First contact	Astrographic Equat.	225	8 38 38		A. E.
2	III.	Bisection	,,	,,	8 42 7	8 39	,,
2	III.	Last contact	,,	,,	8 55 5		,,
3	I. (*b*)	Tr. Ing. First contact	,,	,,	9 0 47	9 2	C. D.
3	I.	Last contact	,,	,,	9 4 39		,,
19	I.	Tr. Ing. Bisection	Merz. Refractor	130	7 25 25	7 24	B.
19	I.	Last contact	,,	,,	7 29 58		,,
19	I.	Tr. Ing. Last contact	E. Equat.	200	7 28 58	7 24	T. H.
27	I. (*c*)	Occ. D. Bisection	Merz. Refractor	295	6 44 30	6 43	L.
27	I.	Last seen	,,	,,	6 45 10		,,
27	I. (*d*)	Occ. D. First contact	E. Equat.	200	6 40 24		H.
27	I.	Bisection	,,	,,	6 41 59	6 43	,,
27	I.	Last seen	,,	,,	6 44 33		,,
27	I. (*e*)	Occ. D. Last seen	Altaz.	100	6 44 19	6 43	B.
Feb. 4	I.	Tr. Ing. First contact	Merz. Refractor	285	5 50 15		L.
4	I.	Bisection	,,	,,	5 51 58	5 50	,,
4	I.	Last contact	,,	,,	5 54 14		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Feb. 4	I.	Tr. Ing.	First contact	E. Equat.	200	5 45 58		D. E.
4	I.		Bisection	,,	,,	5 47 47	5 50	,,
4	I.		Last contact	,,	,,	5 49 57		,,
4	I.	Tr. Egr.	First contact	Altaz.	100	8 6 25		B.
4	I. (*f*)		Last contact	,,	,,	8 8 28	8 5	,,
4	I.	Tr. Egr.	First contact	E. Equat.	200	8 1 25		D. E.
4	I.		Bisection	,,	,,	8 3 55	8 5	,,
4	I.		Last contact	,,	,,	8 6 5		,,
5	I. (*g*)	Ecl. R.	First seen	,,	,,	6 35 24		A. C.
5	I.		Full brightness	,,	,,	6 36 51	6 35 1	,,
5	I.	Ecl. R.	Full brightness	Astrographic Equat.	225	6 35 49	6 35 1	H. F.
7	III.	Tr. Egr.	First contact	E. Equat.	200	7 55 22		H.
7	III.		Bisection	,,	140	8 0 21	7 57	,,
7	III.		Last contact	,,	,,	8 3 31		,,
19	I.	Occ. D.	Bisection	,,	100	7 11 54		,,
19	I.		Last seen	,,	,,	7 13 49	7 12	,,
25	III.	Occ. R.	First seen	,,	,,	6 40 28		,,
25	III.		Bisection	,,	,,	6 42 17	6 44	,,
25	III.		Last contact	,,	,,	6 44 47		,,
28	I. (*h*)	Ecl. R.	First seen	Finder of Merz. Refractor	50	6 50 58		L.
28	I.		Full brightness	,,	,,	6 52 56	6 50 11	,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Feb. 28	I. (*i*)	Ecl. R.	First seen	Astrographic Equat.	225	6 50 22		C. D.
28	I.		Bisection	,,	,,	6 51 37	6 50 11	,,
28	I.		Full brightness	,,	,,	6 53 22		,,
Mar. 23	I.	Ecl. R.	First seen	E. Equat.	100	7 4 53	7 4 27	H.
23	I.		Full brightness	,,	,,	7 6 52		,,
23	I. (*j*)	Ecl. R.	First seen	Astrographic Equat.	225	7 5 9		C. D.
23	I.		Bisection	,,	,,	7 5 59	7 4 27	,,
23	I.		Full brightness	,,	,,	7 7 9		,,
July 5	I. (*k*)	Ecl. D.	Began to fade	,,	,,	15 2 29		,,
5	I.		Bisection	,,	,,	15 3 29	15 3 48	,,
5	I.		Last seen	,,	,,	15 4 21		,,
22	III.	Tr. Egr.	Bisection	,,	,,	13 48 46	13 54	,,
22	III.		Last contact	,,	,,	13 51 40		,,
22	I.	Tr. Egr.	First contact	,,	,,	13 56 59		,,
22	I.		Bisection	,,	,,	13 59 14	14 3	,,
22	I.		Last contact	,,	,,	14 1 58		,,
Aug. 14	I. (*l*)	Tr. Ing.	Last contact	E. Equat.	200	12 5 0	12 10	B.
14	I.	Tr. Egr.	Bisection	Astrographic Equat.	225	14 18 59	14 21	C. D.
14	I.		Last contact	,,	,,	14 20 14		,,
15	I.	Occ. R.	First seen	E. Equat.	275	11 33 18	11 30	L.
15	I. (*m*)		Last contact	,,	,,	11 35 57		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Aug. 24	II.	Ecl. D.	Last seen	Altaz.	100	13 38 58	13 39 41	B.
Sept. 3	III.	Tr. Ing.	First contact	Astrographic Equat.	225	12 46 43		C. D
3	III.		Bisection	,,	,,	12 57 11	12 51	,,
3	III.		Last contact	,,	,,	13 9 14		,,
4	II. (*s*)	Occ. R.	First seen	Altaz.	100	10 42 12	10 31	H. F.
4	II.		Last contact	,,	,,	10 46 21		,,
5	I. (*o*)	Ecl. D.	Began to fade	Astrographic Equat.	225	13 36 55		C. D.
5	I.		Bisection	,,	,,	13 38 33	13 39 18	,,
5	I.		Last seen	,,	,,	13 40 13		,,
7	I. (*p*)	Occ. R.	First seen	,,	,,	11 35 25		H. F.
7	I.		Bisection	,,	,,	11 36 20	11 37	,,
7	I.		Last contact	,,	,,	11 39 10		,,
11	II.	Occ. D.	First contact	,,	,,	10 44 30	10 45	A. E.
11	II.		Last seen	,,	,,	10 47 14		,,
14	I. (*q*)	Ecl. D.	Last seen	,,	,,	10 2 5	10 1 41	C. D.
22	I.	Tr. Ing.	First contact	E. Equat.	360	10 24 40		A. C.
22	I.		Bisection	,,	,,	10 26 21	10 26	,,
22	I.		Last contact	,,	,,	10 28 7		,,
22	I.	Tr. Egr.	First contact	,,	,,	12 31 23		,,
22	I.		Bisection	,,	,,	12 33 7	12 37	,,
22	I.		Last contact	,,	,,	12 34 56		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Feb. 28	I. (*i*)	Ecl. R.	First seen	Astrographic Equat.	225	6 50 22		C. D.
28	I.		Bisection	,,	,,	6 51 37	6 50 11	,,
28	I.		Full brightness	,,	,,	6 53 22		,,
Mar. 23	I.	Ecl. R.	First seen	E. Equat.	100	7 4 53	7 4 27	H.
23	I.		Full brightness	,,	,,	7 6 52		,,
23	I. (*j*)	Ecl. R.	First seen	Astrographic Equat.	225	7 5 9		C. D.
23	I.		Bisection	,,	,,	7 5 59	7 4 27	,,
23	I.		Full brightness	,,	,,	7 7 9		,,
July 5	I. (*k*)	Ecl. D.	Began to fade	,,	,,	15 2 29		,,
5	I.		Bisection	,,	,,	15 3 29	15 3 48	,,
5	I.		Last seen	,,	,,	15 4 21		,,
22	III.	Tr. Egr.	Bisection	,,	,,	13 48 46	13 54	,,
22	III.		Last contact	,,	,,	13 51 40		,,
22	I.	Tr. Egr.	First contact	,,	,,	13 56 59		,,
22	I.		Bisection	,,	,,	13 59 14	14 3	,,
22	I.		Last contact	,,	,,	14 1 58		,,
Aug. 14	I. (*l*)	Tr. Ing.	Last contact	E. Equat.	200	12 5 0	12 10	B.
14	I.	Tr. Egr.	Bisection	Astrographic Equat.	225	14 18 59	14 21	C. D.
14	I.		Last contact	,,	,,	14 20 14		,,
15	I.	Occ. R.	First seen	E. Equat.	275	11 33 18	11 30	L.
15	I. (*m*)		Last contact	,,	,,	11 35 57		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Aug. 24	II.	Ecl. D.	Last seen	Altaz.	100	13 38 58	13 39 41	B.
Sept. 3	III.	Tr. Ing.	First contact	Astrographic Equat.	225	12 46 43		C. D
3	III.		Bisection	,,	,,	12 57 11	12 51	,,
3	III.		Last contact	,,	,,	13 9 14		,,
4	II. (*n*)	Occ. R.	First seen	Altaz.	100	10 42 12	10 31	H. F.
4	II.		Last contact	,,	,,	10 46 21		,,
5	I. (*o*)	Ecl. D.	Began to fade	Astrographic Equat.	225	13 36 55		C. D.
5	I.		Bisection	,,	,,	13 38 33	13 39 18	,,
5	I.		Last seen	,,	,,	13 40 13		,,
7	I. (*p*)	Occ. R.	First seen	,,	,,	11 35 25		H. F.
7	I.		Bisection	,,	,,	11 36 20	11 37	,,
7	I.		Last contact	,,	,,	11 39 10		,,
11	II.	Occ. D.	First contact	,,	,,	10 44 30	10 45	A. E.
11	II.		Last seen	,,	,,	10 47 14		,,
14	I. (*q*)	Ecl. D.	Last seen	,,	,,	10 2 5	10 1 41	C. D.
22	I.	Tr. Ing.	First contact	E. Equat.	360	10 24 40		A. C.
22	I.		Bisection	,,	,,	10 26 21	10 26	,,
22	I.		Last contact	,,	,,	10 28 7		,,
22	I.	Tr. Egr.	First contact	,,	,,	12 31 23		,,
22	I.		Bisection	,,	,,	12 33 7	12 37	,,
22	I.		Last contact	,,	,,	12 34 56		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Sept. 23	I. (*r*)	Occ. R.	Bisection	E. Equat.	70	9 52 41	9 45	H.
23	I.		Last contact	,,	,,	9 55 11		,,
25	II.	Ecl. D.	Last seen	,,	,,	13 18 5	13 20 4	D. E.
27	II.	Tr. Egr.	First contact	,,	200	11 56 22		H.
27	II.		Bisection	,,	,,	11 58 47	12 1	,,
27	II.		Last contact	,,	,,	12 3 0		,,
30	I. (*s*)	Occ. R.	First seen	,,	,,	11 31 27		O. T.
30	I.		Bisection	,,	,,	11 32 37	11 33	,,
30	I.		Last contact	,,	,,	11 34 11		,,
Oct. 4	II.	Tr. Ing.	First contact	,,	,,	12 4 23		A. C.
4	II.		Bisection	,,	,,	12 7 6	12 9	,,
4	II.		Last contact	,,	,,	12 12 0		,,
6	II. (*t*)	Occ. R.	First seen	,,	,,	9 26 40	9 26	D. E.
22	II.	Tr. Egr.	First contact	Astrographic Equat.	225	8 10 9		C. D.
22	II.		Bisection	,,	,,	8 11 43	8 13	,,
22	II.		Last contact	,,	,,	8 14 23		,,
22	I.	Tr. Ing.	First contact	,,	,,	11 57 46		,,
22	I.		Bisection	,,	,,	12 0 11	11 59	,,
22	I.		Last contact	,,	,,	12 2 45		,,
22	I.	Sh. Egr.	First contact	,,	,,	13 27 32		,,
22	I.		Bisection	,,	,,	13 29 13	13 30	,,
22	I.		Last contact	,,	,,	13 30 11		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Oct. 24	I. (*u*)	Tr. Egr.	First contact	E. Equat.	200	8 29 53	8 36	L.
24	I.		Last contact	,,	,,	8 35 52		,,
27	II. (*v*)	Ecl. D.	Last seen	,,	,,	12 57 57	12 58 6	B.
31	I. (*w*)	Tr. Ing.	Last contact	Astrographic Equat.	225	8 13 58	8 9	C. D.
31	I. (*x*)	Tr. Egr.	First contact	,,	,,	10 12 39		D. E.
31	I.		Bisection	,,	,,	10 16 23	10 20	,,
31	I.		Last contact	,,	,,	10 18 33		,,
Nov. 3	III. (*y*)	Ecl. R.	Full brightness	E. Equat.	100	6 39 8	6 40 21	A. C.
3	III.	Occ. D.	First contact	,,	,,	6 42 59		,,
3	III.		Bisection	,,	,,	6 52 42	6 52	,,
3	III. (*z*)		Last seen	,,	,,	7 6 15		,,
6	I.	Ecl. D.	Began to fade	,,	,,	12 11 16		L.
6	I.		Half brightness	,,	,,	12 15 46	12 18 57	,,
6	I.		Quarter brightness	,,	,,	12 18 5		,,
6	I.		Last seen	,,	,,	12 19 15		,,
6	I.	Ecl. D.	Last seen	Astrographic Equat.	225	12 19 28	12 18 57	A. E.
9	I. (*a'*)	Tr. Egr.	First contact	,,	,,	6 25 52		H. F.
9	I.		Bisection	,,	,,	6 27 57	6 29	,,
9	I.		Last contact	,,	,,	6 30 12		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Nov. 16	I.	Tr. Egr.	Bisection	E. Equat.	100	8 12 14	8 13	H.
16	I.		Last contact	,,	,,	8 13 59		,,
16	I.	Tr. Egr.	Bisection	Altaz.	,,	8 11 7	8 13	C. D.
16	I.		Last contact	,,	,,	8 13 21		,,
22	I.	Occ. D.	First contact	E. Equat.	,,	10 28 2	10 29	L.
22	I.		Last seen	,,	,,	10 31 6		,,
22	I. (b')	Occ. D.	First contact	Astrographic Equat.	225	10 26 14		H. F.
22	I.		Bisection	,,	,,	10 29 18	10 29	,,
22	I.		Last seen	,,	,,	10 30 55		,,
22	I. (c')	Occ. D.	First contact	Altaz.	100	10 25 44		D. E.
22	I.		Bisection	,,	,,	10 27 44	10 29	,,
22	I.		Last seen	,,	,,	10 29 35		,,
Dec. 7	II.	Tr. Ing.	Bisection	E. Equat.	,,	8 39 57	8 42	H.
7	II.		Last contact	,,	,,	8 42 37		,,
7	II. (d')	Tr. Ing.	First contact	Astrographic Equat.	225	8 36 14		C. D.
7	II.		Bisection	,,	,,	8 38 56	8 42	,,
7	II.		Last contact	,,	,,	8 41 33		,,
7	II.	Tr. Egr.	First contact	E. Equat.	100	10 52 36		H.
7	II.		Bisection	,,	,,	10 55 35	10 59	,,
7	II.		Last contact	,,	,,	10 59 19		,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Dec. 7	II.	Tr. Egr. First contact	Astrographic Equat.	225	10 50 12		C. D.
7	II.	Bisection	,,	,,	10 53 12	10 59	,,
7	II.	Last contact	,,	,,	10 56 16		,,
7	I.	Tr. Ing. First contact	E. Equat.	100	11 9 18		H.
7	I.	Bisection	,,	,,	11 11 32	11 12	,,
7	I.	Last contact	,,	,,	11 14 42		,,
7	I.	Tr. Ing. First contact	Astrographic Equat.	225	11 11 35		C. D.
7	I.	Bisection	,,	,,	11 13 50	11 12	,,
7	I.	Last contact	,,	,,	11 16 29		,,
7	II.	Sh. Egr. Bisection	,,	,,	11 56 53	12 0	,,
7	II.	Last contact	,,	,,	11 59 2		,,
9	II.	Ecl. R. First seen	E. Equat.	100	6 43 13	6 42 57	B.
9	II. (e′)	Ecl. R. First seen	Astrographic Equat.	225	6 43 1		H. F.
9	II.	Bisection	,,	,,	6 44 46	6 42 57	,,
9	II.	Full brightness	,,	,,	6 46 55		,,
9	I.	Tr. Egr. Last contact	,,	,,	7 52 40	7 50	,,
14	II.	Tr. Ing. Bisection	E. Equat.	200	10 59 9	11 0	C. D.
14	II.	Last contact	,,	,,	11 2 43		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1893 Dec. 14	I.	Tr. Ing.	First contact	E. Equat.	200	12 56 51		C. D.
14	I.		Bisection	,,	,,	12 58 44	12 57	,,
14	I.		Last contact	,,	,,	13 1 23		,,
14	II.	Tr. Egr.	Last contact	,,	,,	13 17 1	13 18	,,
15	I.	Ecl. R.	First seen	,,	275	13 0 8	13 0 31	B.
16	II. (*f'*)	Ecl. R.	First seen	,,	100	9 18 21		L.
16	II.		Bisection	,,	,,	9 19 36	9 18 21	,,
16	II.		Full brightness	,,	,,	9 20 56		,,
16	I.	Tr. Egr.	First contact	,,	,,	9 32 19	9 35	L.
16	I.		Last contact	,,	,,	9 35 39		,,
22	I.	Occ. D.	First contact	,,	55	11 54 11		W. B.
22	I.		Bisection	,,	,,	11 55 41	11 56	,,
22	I.		Last seen	,,	,,	11 56 56		,,
23	III.	Occ. R.	Last contact	,,	100	7 23 0	7 27	A. C.
23	II.	Occ. D.	First contact	,,	,,	7 53 10		,,
23	II.		Bisection	,,	,,	7 55 23	7 56	,,
23	II.		Last seen	,,	,,	7 57 41		,,
23	I. (*g'*)	Tr. Ing.	First contact	Transit Circle	195	9 9 49	9 9	,,
23	I.		Last contact	E. Equat.	100	9 14 3		,,
23	III. (*h'*)	Ecl. D.	Last seen	,,	,,	9 17 30	9 15 31	,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m	Observer.
1893 Dec. 30	III.	Occ. D. First contact	E. Equat.	100	9 15 15		W. B.
30	III.	Bisection	,,	,,	9 17 0	9 16	,,
30	III.	Last contact	,,	,,	9 19 14		,,
30	I.	Tr. Ing. First contact	,,	,,	10 58 18		,,
30	I.	Bisection	,,	,,	10 59 28	10 57	,,
30	I.	Last contact	,,	,,	11 0 58		,,

Notes.

(*a*) Image tremulous, windy. (*b*) A bad observation. *Jupiter* very faint; satellite almost invisible; both times uncertain. (*c*) Very good observation. (*d*) Bad observation, probably late. (*e*) Very rough observation. (*f*) Bad observation. (*g*) Good observation. (*h*) A good observation, at $6^h\ 52^m\ 12^s$ brightness equal to, and at $6^h\ 52^m\ 39^s$ brightness greater than, that of Satellite IV. (*i*) Sky hazy. (*j*) Bad observation; definition very poor. (*k*) Nearly daylight. (*l*) Bad definition. (*m*) This observation is of little value. Could get no definite limb on *Jupiter*, and the satellite was very faint. Times probably half a minute late. (*n*) Definition very bad. Observation not worth much. (*o*) Definition very poor. (*p*) Definition of *Jupiter* rather poor. (*q*) Definition bad. (*r*) Not a good observation. (*s*) *Jupiter's* limb rather hazy. (*t*) Cloudy. (*u*) Not a good observation. Satellite seen through thin cloud. (*v*) Definition not good. Very hazy. (*w*) Definition bad. (*x*) Definition bad. (*y*) Reappeared almost in contact with *Jupiter*; probably late. (*z*) Rough observation, through a momentary break in clouds. (*a'*) Definition poor. (*b'*) Considered good observation. Definition very good. (*c'*) Very little use, no definition; probably late. (*d'*) Definition poor. (*e'*) Definition good. (*f'*) Very good observation. (*g'*) Observed as *Jupiter* was crossing the first wire. (*h'*) Not a good observation. Very misty.

The initials H. T., L., H., A. C., B., T. H., H. F., C. M., C. D., D. E., W. B., O. T., and A. E., are those of Mr. Turner, Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Hudson, Mr. Furner, Mr. Martin, Mr. Davidson, Mr. Edney, Mr. Bowyer, Mr. Tuck, and Miss Everett respectively.

Ephemerides of the Five Inner Satellites of Saturn, 1894.

By A. Marth.

Greenwich Noon. 1894.	P	L	B	*B*	A−L	Long. of Centr. Mer.	B′
Feb. 20	358°·520	203°·765	+13°·954	+12°·250	−4°·485	117°·54	+15°·43
25	·502	203·609	13·869	12·315	4·178	22·01	15·34
Mar. 2	·480	203·416	13·770	12·380	3·833	286·49	15·23
7	·454	203·189	13·658	12·445	3·454	190·98	15·11
12	·423	202·931	13·535	12·510	3·044	95·47	14·97
17	·389	202·646	13·402	12·575	2·607	359·95	14·83
22	·353	202·337	13·261	12·640	2·146	264·42	14·67
27	358·315	202·008	13·113	12·705	−1·666	168·88	14·51
Apr. 1	·275	201·664	12·961	12·770	1·170	73·32	14·34
6	·233	201·310	12·806	12·835	0·663	337·73	14·17
11	·191	200·950	12·651	12·900	−0·151	242·11	14·00
16	·149	200·589	12·497	12·965	+0·362	146·46	13·83
21	·108	200·233	12·347	13·029	0·870	50·76	13·67
26	·068	199·885	12·203	13·094	1·370	315·02	13·51
May 1	358·029	199·550	+12·066	+13·159	+1·858	219·23	+13·36
6	357·992	199·232	11·938	13·243	2·328	123·39	13·22
11	·958	198·936	11·821	13·287	2·776	27·49	13·09
16	·927	198·665	11·717	13·351	3·200	291·54	12·97
21	·899	198·421	11·626	13·415	3·596	195·53	12·88
26	·875	198·207	11·550	13·479	3·962	99·46	12·79
31	·854	198·026	11·490	13·542	4·295	3·34	12·73
June 5	357·837	197·881	11·447	13·606	+4·593	267·16	12·68
10	·824	197·772	11·420	13·669	4·855	170·92	12·65
15	·816	197·700	11·411	13·732	5·080	74·63	12·64
20	·812	197·666	11·419	13·795	5·267	338·29	12·65
25	·812	197·670	11·445	13·858	5·415	241·90	12·68
30	·817	197·713	11·488	13·921	5·525	145·46	12·73
July 5	·826	197·794	11·548	13·984	5·597	48·98	12·79
10	357·840	197·913	+11·624	+14·047	+5·631	312·46	+12·87

P denotes the position-angle of the axis of *Saturn*; L + 180° the planetocentric longitude of the Earth referred to the assumed

plane of the planet's equator; $\Lambda + 180°$ that of the Sun, or $\Lambda - L$ the difference between the two. B and B denote the planetocentric latitudes of the Earth and Sun above the assumed plane.

The longitudes of *Saturn's* central meridian depend on the values adopted in the ephemeris for 1893. The various surface markings, observed by Mr. A. S. Williams during the last apparition of the planet, indicate such variations in the rate of motion that, for the present, it seemed the safer course not to make any alteration. The adopted daily rate of rotation is 844°·80, corresponding to a period of $10^h\ 13^m{\cdot}636$. The differences between successive values of the longitude of the central meridian, for the interval of five days, vary between 4223°·48 and 4224°·49.

If on the planet's spheroidal surface, ω is the longitude of a marking, ω_0 that of the central meridian, β the planetocentric latitude of the marking, a and b the semi-axes of the apparent disc as seen from a distant point in planetocentric latitude B, the apparent co-ordinates of the marking, referred to the axes of the disc, will be

$$s \sin (p - P) = x = a \cos \beta' \sin (\omega - \omega_0)$$
$$s \cos (p - P) = y = b \sin (\beta' - B') + x \sin B \tan \tfrac{1}{2} (\omega - \omega_0),$$

wherein

$$\tan \beta' = \tan \beta \,.\, \sec \epsilon_0$$
$$\tan B' = \tan B \,.\, \sec \epsilon_0,$$

$e = \sin \epsilon_0$ being the eccentricity of the spheroid or $\cos \epsilon_0$ the proportion of its polar to its equatorial diameter. The results of the measurements for the determination of the ellipticity of the ball of *Saturn*, while the ring appeared as a thin line, having not yet become known, I have again assumed $\cos \epsilon_0$ to be 0·900.

In the tables for the five satellites a and b denote the semi-axes of the apparent orbits, $l - L$ the orbital longitudes reckoned from the points which are in superior conjuction with the planet's centre or in opposition to the Earth in longitude. By adding to $l - L$ the value of L from the preceding table, the longitudes l are found, which are already corrected for the equation of light.

Greenwich Noon.	Semidiameter of Ball. Equat.	Phase.	Polar.	Semiaxis of Ring. Major	Minor.	*Mimas.* a_1	b_1	l_1-L	Diff.
1894.	″	″	″	″	″	″	″	°	°
Feb. 20	8·99	0·027	8·14	20·71	5·00	28·31	+6·83	302·47	1910·32
25	9·05	·024	8·20	20·86	5·00	28·51	6·83	52·79	·34
Mar. 2	9·11	·020	8·25	21·00	5·00	28·70	6·83	163·13	·36
7	9·16	·017	8·30	21·13	4·99	28·87	6·82	273·49	·38
12	9·21	·013	8·34	21·24	4·97	29·02	6·79	23·87	·40
17	9·26	·010	8·38	21·34	4·95	29·16	6·76	134·27	·40
22	9·29	·007	8·41	21·42	4·91	29·27	6·71	244·67	·40
27	9·32	·004	8·44	21·49	4·87	29·36	6·66	355·07	·41
Apr. 1	9·34	·001	8·46	21·53	4·83	29·43	6·60	105·48	·40
6	9·35	·000	8·47	21·56	4·78	29·47	6·53	215·88	·39
11	9·36	...	8·47	21·57	4·73	29·48	6·46	326·27	1910·37
16	9·35	·000	8·47	21·56	4·67	29·47	6·38	76·64	·35
21	9·34	·001	8·46	21·54	4·61	29·43	6·29	186·99	·33
26	9·32	·003	8·44	21·49	4·54	29·37	6·21	297·32	·30
May 1	9·30	·005	8·41	21·43	4·48	29·28	+6·12	47·62	·26
6	9·26	·008	8·38	21·35	4·42	29·17	6·03	157·88	·23
11	9·22	·011	8·34	21·25	4·35	29·04	5·95	268·11	·19
16	9·17	·015	8·29	21·14	4·29	28·89	5·87	18·30	·15
21	9·12	·018	8·24	21·02	4·24	28·72	5·79	128·45	·11
26	9·06	·022	8·19	20·88	4·18	28·54	5·71	238·56	·06
31	9·00	·025	8·14	20·74	4·13	28·34	5·64	348·62	1910·02
June 5	8·93	·029	8·08	20·59	4·09	28·13	5·58	98·64	1909·97
10	8·86	·032	8·01	20·43	4·05	27·92	5·53	208·61	·93
15	8·79	·034	7·95	20·27	4·01	27·69	5·48	318·54	·88
20	8·72	·037	7·88	20·10	3·98	27·46	5·44	68·42	·84
25	8·65	·039	7·82	19·93	3·95	27·23	5·40	178·26	·80
30	8·57	·040	7·75	19·76	3·93	27·00	5·38	288·06	·76
July 5	8·50	·041	7·69	19·59	3·92	26·77	5·36	37·82	1909·72
10	8·42	0·041	7·62	19·42	3·91	26·54	+5·35	147·54	

		Enceladus.				*Tethys.*			
		a_2	b_2	l_2-L	Diff.	a_2	b_2	l_2-L	Diff.
1894		"	"	°	°	"	"	°	°
Feb.	20	36·31	+8·76	45·47	1313·91	44·95	+10·84	292·35	953·71
	25	36·57	8·77	279·38	·94	45·27	10·85	166·06	·75
Mar.	2	36·81	8·76	153·32	·97	45·57	10·85	39·81	·77
	7	37·03	8·74	27·29	1313·99	45·84	10·83	273·58	·80
	12	37·24	8·71	261·28	1314·00	46·09	10·79	147·38	·82
	17	37·41	8·67	135·28	·02	46·30	10·73	21·20	·83
	22	37·55	8·61	9·30	·03	46·48	10·66	255·03	·85
	27	37·66	8·55	243·33	·03	46·62	10·58	128·88	·85
Apr.	1	37·75	8·47	117·36	·03	46·73	10·48	2·73	·85
	6	37·80	8·38	351·39	·03	46·79	10·37	236·58	·85
	11	37·82	8·28	225·42	·01	46·81	10·25	110·43	·85
	16	37·80	8·18	99·43	1314·00	46·80	10·12	344·28	·83
	21	37·75	8·07	333·43	1313·98	46·74	9·99	218·11	·81
	26	37·67	7·96	207·41	·96	46·64	9·86	91·92	953·80
May	1	37·56	+7·85	81·37	·93	46·50	+9·72	325·72	·77
	6	37·42	7·74	315·30	·89	46·33	9·58	199·49	·74
	11	37·25	7·63	189·19	·86	46·12	9·45	73·23	·71
	16	37·06	7·53	63·05	·83	45·88	9·32	306·94	·67
	21	36·85	7·43	296·88	·79	45·61	9·19	180·61	·63
	26	36·61	7·33	170·67	·74	45·32	9·07	54·24	·60
	31	36·36	7·24	44·41	·70	45·01	8·97	287·84	·56
June	5	36·09	7·16	278·11	·67	44·68	8·87	161·40	·52
	10	35·81	7·09	151·78	·62	44·33	8·78	34·92	·48
	15	35·52	7·03	25·40	·57	43·98	8·70	268·40	·44
	20	35·23	6·98	258·97	·54	43·61	8·63	141·84	·40
	25	34·93	6·93	132·51	·49	43·24	8·58	15·24	·35
	30	34·64	6·90	6·00	·46	42·88	8·54	248·59	·31
July	5	34·34	6·87	239·46	1313·41	42·51	8·51	121·90	953·28
	10	34·04	+6·86	112·87		42·14	+8·49	335·18	

		Dione.				*Rhea.*			
1894.		a_s	b_s	$l_s-L.$	Diff.	a_s	b_s	$l_s-L.$	Diff.
		″	″	°	°	″	″	°	°
Feb.	20	57·57	+13·88	17·31	657·86	80·40	+19·39	357·83	398·63
	25	57·98	13·90	315·90	·91	80·97	19·41	36·46	·67
Mar.	2	58·36	13·89	253·10	·94	81·51	19·40	75·13	·71
	7	58·71	13·86	191·04	·97	82·00	19·36	113·84	·73
	12	59·03	13·81	129·01	657·99	82·44	19·29	152·57	·76
	17	59·30	13·74	67·00	658·01	82·82	19·19	191·33	·77
	22	59·53.	13·66	5·01	·02	83·14	19·07	230·10	·79
	27	59·71	13·55	303·03	·03	83·39	18·92	268·89	·80
Apr.	1	59·85	13·42	241·06	·04	83·58	18·75	307·69	·81
	6	59·93	13·28	179·10	·04	83·69	18·55	346·50	·81
	11	59·96	13·13	117·14	·03	83·73	18·34	25·31	·81
	16	59·94	12·97	55·17	·03	83·70	18·11	64·12	·80
	21	59·86	12·80	353·20	658·01	83·59	17·87	102·92	·79
	26	59·73	12·63	291·21	657·99	83·41	17·63	141·71	·78
May	1	59·56	+12·45	229·20	·96	83·17	+17·38	180·49	398·75
	6	59·33	12·27	167·16	·94	82·86	17·14	219·24	·73
	11	59·07	12·10	105·10	·92	82·49	16·90	257·97	·70
	16	58·76	11·93	43·02	·88	82·06	16·66	296·67	·67
	21	58·42	11·77	340·90	·84	81·58	16·44	335·34	·64
	26	58·04	11·62	278·74	·81	81·06	16·23	13·98	·60
	31	57·64	11·48	216·55	657·77	80·50	16·04	52·58	·56
June	5	57·22	11·36	154·32	·73	79·91	15·86	91·14	·53
	10	56·78	11·24	92·05	·69	79·29	15·70	129·67	·49
	15	56·32	11·14	29·74	·65	78·65	15·56	168·16	·45
	20	55·86	11·06	327·39	·61	78·00	15·44	206·61	·41
	25	55·39	10·99	265·00	·57	77·35	15·35	245·02	·37
	30	54·91	10·94	202·57	·53	76·69	15·27	283·39	·33
July	5	54·44	10·90	140·10	657·49	76·03	15·22	321·72	398·30
	10	53·97	+10·87	77·59		75·37	+15·19	0·02	

These values are to be interpolated for the times for which the apparent places of the satellites are required when the position-angles p and distances s, or the rectangular coordinates x and y referred to the axes of the disc of *Saturn*, are found by means of the formulæ:

$$s \sin (p-P) = x = a \sin (l-L)$$
$$s \cos (p-P) = y = b \cos (l-L).$$

The adopted zero-meridian will pass the centre of the disc of *Saturn* at the following Greenwich mean times:

1894.	h m	h m	1894.	h m	h m
Feb. 20	6 53·2	17 6·8	Mar. 29	8 33·6	18 47·2
21	13 33·9	23 47·3	30	5 0·7	15 14·3
22	10 1·1	20 14·6	31	11 41·5	21 55·0
23	6 28·2	16 41·8	Apr. 1	8 8·6	18 22·2
24	13 8·9	23 22·5	2	4 35·8	14 49·3
25	9 36·1	19 49·6	3	11 16·5	21 30·1
26	6 3·2	16 16·8	4	7 43·6	17 57·2
27	12 43·9	22 57·5	5	4 10·8	14 24·4
28	9 11·0	19 24·6	6	10 51·5	21 5·1
Mar. 1	5 38·2	15 51·7	7	7 18·7	17 32·3
2	12 18·9	22 32·4	8	3 45·9	13 59·4
3	8 46·0	18 59·6	9	10 26·6	20 40·2
4	5 13·1	15 26·7	10	6 53·8	17 7·3
5	11 53·8	22 7·4	11	3 20·9	13 34·5
6	8 20·9	18 34·5	12	10 1·7	20 15·3
7	4 48·1	15 1·6	13	6 28·8	16 42·4
8	11 28·7	21 42·3	14	2 56·0	13 9·6
9	7 55·9	18 9·4	15	9 36·8	19 50·4
10	4 23·0	14 36·6	16	6 4·0	16 17·6
11	11 3 7	21 17·3	17	2 31·1	12 44·7
12	7 30·8	17 44·4	18	9 11·9	19 25·5
13	3 58·0	14 11·5	19	5 39·1	15 52·7
14	10 38·7	20 52·2	20	2 6·3	12 19·9
15	7 5·8	17 19·4	21	8 47·1	19 0 7
16	3 32·9	13 46·5	22	5 14·3	15 27·9
17	10 13·6	20 27·2	23	1 41·5	11 55·1
18	6 40·8	16 54·3	24	8 22·3	18 35·9
19	3 7·9	13 21·5	25	4 49·5	15 3·1
20	9 48·6	20 2·2	26	1 16·7	11 30·3
21	6 15·8	16 29·3	27	7 57·5	18 11·1
22	2 42·9	12 56·5	28	4 24·7	14 38·3
23	9 23 6	19 37·2	29	11 5·5	21 19·1
24	5 50·7	16 4·3	30	7 32·7	17 46·3
25	2 17·9	12 31·5	May 1	3 59·9	14 13·5
26	8 58·6	19 12·2	2	10 40·8	20 54·4
27	5 25·7	15 39·3	3	7 8 0	17 21·6
28	12 6·4	22 20·0	4	3 35·2	13 48·8

1894.	h	m	h	m	1894.	h	m	h	m
May 5	10	16·1	20	29·7	June 7	5	46·6	16	0·3
6	6	43·3	16	56·9	8	2	13·9	12	27·6
7	3	10·5	13	24·2	9	8	55·0	19	8·6
8	9	51·4	20	5·0	10	5	22·3	15	36·0
9	6	18·6	16	32·3	11	1	49·7	12	3·3
10	2	45·9	12	59·5	12	8	30·7	18	44·4
11	9	26·8	19	40·4	13	4	58·1	15	11·7
12	5	54·0	16	7·6	14	1	25·4	11	39·1
13	2	21·3	12	34·9	15	8	6·5	18	20·1
14	9	2·2	19	15·8	16	4	33·8	14	47·5
15	5	29·4	15	43·1	17	1	1·2	11	14·9
16	1	56·7	12	10·3	18	7	42·2	17	55·9
17	8	37·6	18	51·2	19	4	9·6	14	23·3
18	5	4·9	15	18·5	20	0	37·0	10	50·7
19	1	32·1	11	45·8	21	7	18·1	17	31·8
20	8	13·1	18	26·7	22	3	45·5	13	59·1
21	4	40·3	14	54·0	23	0	12·8	10	26·5
22	1	7·6	11	21·3	24	6	53·9	17	7·6
23	7	48·6	18	2·2	25	3	21·3	13	35·0
24	4	15·9	14	29·5	26	10	2·4	20	16·1
25	10	56·8	21	10·5	27	6	29·8	16	43·5
26	7	24·1	17	37·8	28	2	57·2	13	10·9
27	3	51·4	14	5·1	29	9	38·3	19	52·0
28	10	32·4	20	46·0	30	6	5·7	16	19·4
29	6	59·7	17	13·3	July 1	2	33·1	12	46·8
30	3	27·0	13	40·6	2	9	14·2	19	28·0
31	10	8·0	20	21·6	3	5	41·7	15	55·4
June 1	6	35·3	16	48·9	4	2	9·1	12	22·8
2	3	2·6	13	16·3	5	8	50·2	19	3·9
3	9	43·6	19	57·3	6	5	17·6	15	31·3
4	6	10·9	16	24·6	7	1	45·0	11	58·8
5	2	38·3	12	51·9	8	8	26·2	18	39·9
6	9	19·3	19	32·9	9	4	53·6	15	7·3

Approximate Greenwich times of the conjunctions of the satellites with the centre of the planet, or of their crossing the direction of the polar-axis of the ball.

"*n*" satellite north, in superior conjunction, moving from the preceding to the following side.

"*s*" satellite south, in inferior conjunction, moving from the following to the preceding side.

In the case of *Rhea* the times of the greatest elongations, "*e*" east, "*w*" west, are also given.

G.M.T.			G.M.T.			G.M.T.		
1894.	h		1894.	h		1894.	h	
Feb. 20	8·5	Te. *n*	Mar. 1	13·7	Mi. *n*	Mar. 11	0·1	En. *n*
	12·3	En. *s*		19·0	Te. *n*		0·5	Di. *n*
	14·9	Mi. *s*	2	1·1	Mi. *s*		5·2	Rh. *e*
21	2·2	Mi. *n*		2·4	En. *s*		5·5	Te. *n*
	3·7	Rh. *e*		4·5	Rh. *e*		11·2	Mi. *s*
	4·7	En. *n*		12·4	Mi. *n*		16·6	En. *s*
	5·7	Di. *s*		17·6	Te. *s*		22·5	Mi. *n*
	7·2	Te. *s*		18·9	En. *n*	12	4·1	Te. *s*
	13·5	Mi. *s*		19·5	Di. *n*		8·2	Rh. *s*
	21·2	En. *s*		23·7	Mi. *s*		9·0	En. *n*
22	0·8	Mi. *n*	3	7·6	Rh. *s*		9·3	Di. *s*
	5·8	Te. *n*		11·0	Mi. *n*		9·8	Mi. *s*
	6·8	Rh. *s*		11·3	En. *s*		21·1	Mi. *n*
	12·1	Mi. *s*		16·3	Te. *n*	13	1·4	En. *s*
	13·6	En. *n*		22·3	Mi. *s*		2·7	Te. *n*
	14·5	Di. *n*	4	3·7	En. *n*		8·4	Mi. *s*
	23·5	Mi. *n*		4·3	Di. *s*		11·3	Rh. *w*
23	4·5	Te. *s*		9·6	Mi. *n*		17·9	En. *n*
	6·0	En. *s*		10·6	Rh. *w*		18·1	Di. *n*
	9·9	Rh. *w*		14·9	Te. *s*		19·7	Mi. *n*
	10·8	Mi. *s*		20·2	En. *s*	14	1·4	Te. *s*
	22·1	Mi. *n*		20·9	Mi. *s*		7·0	Mi. *s*
	22·5	En. *n*	5	8·2	Mi. *n*		10·3	En. *s*
	23·3	Di. *s*		12·6	En. *n*		14·4	Rh. *n*
24	3·1	Te. *n*		13·2	Di. *n*		18·3	Mi. *n*
	9·4	Mi. *s*		13·6	Te. *n*	15	0·0	Te. *n*
	13·0	Rh. *n*		13·7	Rh. *n*		2·8	En. *n*
	14·9	En. *s*		19·5	Mi. *s*		2·9	Di. *s*
	20·7	Mi. *n*	6	5·1	En. *s*		5·6	Mi. *s*
25	1·7	Te. *s*		6·8	Mi. *n*		16·9	Mi. *n*
	7·4	En. *n*		12·2	Te. *s*		17·5	Rh. *e*
	8·0	Mi. *s*		16·8	Rh. *e*		19·2	En. *s*
	8·2	Di. *n*		18·1	Mi. *s*		22·7	Te. *s*
	16·1	Rh. *e*		21·5	En. *n*	16	4·3	Mi. *s*
	19·3	Mi. *n*		22·0	Di. *s*		11·6	En. *n*
	23·8	En. *s*	7	5·4	Mi. *n*		11·8	Di. *n*
26	0·4	Te. *n*		10·9	Te. *n*		15·6	Mi. *n*
	6·6	Mi. *s*		13·9	En. *s*		20·6	Rh. *s*
	16·2	En. *n*		16·7	Mi. *s*		21·3	Te. *n*
	17·0	Di. *s*		19·9	Rh. *s*	17	2·9	Mi. *s*
	17·9	Mi. *n*	8	4·0	Mi. *n*		4·1	En. *s*
	19·2	Rh. *s*		6·4	En. *n*		14·2	Mi. *n*
	23·0	Te. *s*		6·8	Di. *n*		20·0	Te. *s*
27	5·2	Mi. *s*		9·5	Te. *s*		20·5	En. *n*
	8·7	En. *s*		15·3	Mi. *s*		20·6	Di. *s*
	16·5	Mi. *n*		22·8	En. *s*		23·7	Rh. *w*
	21·7	Te. *n*		23·0	Rh. *w*	18	1·5	Mi. *s*
	22·3	Rh. *w*	9	2·7	Mi. *n*		12·8	Mi. *n*
28	1·1	En. *n*		8·2	Te. *n*		13·0	En. *s*
	1·8	Di. *n*		14·0	Mi. *s*		18·6	Te. *n*
	3·8	Mi. *s*		15·3	En. *n*	19	0·1	Mi. *s*
	15·1	Mi. *n*		15·6	Di. *s*		2·8	Rh. *n*
	17·6	En. *s*	10	1·3	Mi. *n*		5·4	En. *n*
	20·3	Te. *s*		2·1	Rh. *n*		5·4	Di. *n*
Mar. 1	1·4	Rh. *n*		6·8	Te. *s*		11·4	Mi. *n*
	2·4	Mi. *s*		7·7	En. *s*		17·3	Te. *s*
	10·0	En. *n*		12·6	Mi. *s*		21·8	En. *s*
	10·7	Di. *s*		23·9	Mi. *n*		22·7	Mi. *e*

G.M.T.			G.M.T.			G.M.T.		
1894.	h		1894.	h		1894.	h	
Mar. 20	5·8	Rh. *e*	Mar. 28	19·5	En. *n*	Apr. 6	15·5	Te. *n*
	10·0	Mi. *n*		21·5	Mi. *n*		17·2	En. *s*
	14·3	En. *n*	29	3·7	Te. *s*		20·4	Mi. *s*
	15·9	Te. *n*		6·5	Rh. *e*	7	7·1	Rh. *e*
	Transit of Venus *			8·8	Mi. *s*		7·7	Mi. *n*
	21·3	Mi. *s*		12·0	En. *s*		9·0	Di. *n*
	Transit of Mercury*			20·1	Mi. *n*		9·7	En. *n*
21	6·7	En. *s*	30	2·4	Te. *n*		14·2	Te. *s*
	8·6	Mi. *n*		4·0	Di. *n*		19·0	Mi. *s*
	8·9	Rh. *s*		4·4	En. *n*	8	2·1	En. *s*
	14·6	Te. *s*		7·5	Mi. *s*		6·3	Mi. *n*
	19·9	Mi. *s*		9·6	Rh. *s*		10·2	Rh. *s*
	23·1	Di. *n*		18·8	Mi. *n*		12·8	Te. *n*
	23·1	En. *n*		20·8	En. *s*		17·6	Mi. *s*
22	7·2	Mi. *n*	31	1·0	Te. *s*		17·8	Di. *s*
	12·0	Rh. *w*		6·1	Mi. *s*		18·5	En. *n*
	13·2	Te. *n*		12·7	Rh. *w*	9	4·9	Mi. *n*
	15·6	En. *s*		12·9	Di. *s*		11·0	En. *s*
	18·5	Mi. *s*		13·3	En. *n*		11·5	Te. *s*
23	5·9	Mi. *n*		17·4	Mi. *n*		13·3	Rh. *w*
	7·9	Di. *s*		23·7	Te. *n*		16·2	Mi. *s*
	8·0	En. *n*	Apr. 1	4·7	Mi. *s*	10	2·6	Di. *n*
	11·8	Te. *s*		5·7	En. *s*		3·4	En. *n*
	15·1	Rh. *n*		15·7	Rh. *n*		3·5	Mi. *n*
	17·2	Mi. *s*		16·0	Mi. *n*		10·1	Te. *n*
24	0·5	En. *s*		21·7	Di. *n*		14·8	Mi. *s*
	4·5	Mi. *n*		22·2	En. *n*		16·4	Rh. *n*
	10·5	Te. *n*		22·3	Te. *s*		19·8	En. *s*
	15·8	Mi. *s*	2	3·3	Mi. *s*	11	1·4	δ of * 6·6^m†
	16·7	Di. *n*		14·6	En. *s*		with prec. end of	
	16·9	En. *n*		14·6	Mi. *n*		ring 49·8″ *n*	
	18·2	Rh. *e*		18·8	Rh. *e*		2·1	Mi. *n*
25	3·1	Mi. *n*		20·9	Te. *n*		3·4	δ of * *w*.
	9·1	Te. *s*	3	1·9	Mi. *s*	centre 40·3″ *n*		
	9·3	En. *s*		6·5	Di. *s*		5·5	δ of * *w*.
	14·4	Mi. *s*		7·0	En. *n*		foll. end of	
	21·2	Rh. *s*		13·2	Mi. *n*		ring 30·3″ *n*	
26	1·6	Di. *s*		19·6	Te. *s*		8·7	Te. *s*
	1·7	Mi. *n*		21·9	Rh. *s*		10·2	close δ of
	1·8	En. *n*		23·5	En. *s*		* with Rh.	
	7·8	Te. *n*	4	0·5	Mi. *s*		11·5	Di. *s*
	13·0	Mi. *s*		11·8	Mi. *n*		12·3	En. *n*
	18·2	En. *s*		15·3	Di. *n*		13·4	Mi. *s*
27	0·3	Mi. *n*		15·9	En. *n*		19·5	Rh. *e*
	0·3	Rh. *w*		18·2	Te. *n*	12	0·7	Mi. *n*
	6·4	Te. *s*		23·1	Mi. *s*		4·7	En. *s*
	10·4	Di. *n*	5	1·0	Rh. *w*		7·4	Te. *n*
	10·7	En. *n*		8·3	En. *s*		12·0	Mi. *s*
	11·6	Mi. *s*		10·4	Mi. *n*		20·3	Di. *n*
	22·9	Mi. *n*		16·9	Te. *s*		21·2	En. *n*
28	3·1	En. *s*		21·7	Mi. *s*		22·5	Rh. *s*
	3·4	Rh. *n*	6	0·2	Di. *s*		23·3	Mi. *n*
	5·1	Te. *n*		0·8	En. *n*	13	6·0	Te. *s*
	10·2	Mi. *s*		4·1	Rh. *n*		10·6	Mi. *s*
	19·2	Di. *s*		9·0	Mi. *n*		13·6	En. *s*

* *V.* Note on the Transit.

† The star 6·6^m is Arg. G. C. 18379, and its apparent place—
$13^h\ 24^m\ 55{\cdot}76^s - 5^\circ\ 55'\ 39{\cdot}5''$.

G.M.T. 1894.	h		G.M.T. 1894.	h		G.M.T. 1894.	h	
Apr. 13	22·0	Mi. *n*	Apr. 23	2·3	Rh. *w*	May 2	3·0	Te. *s*
14	1·6	Rh. *w*		3·7	En. *s*		6·9	Mi. *s*
	4·7	Te. *n*		8·1	Mi. *n*		17·9	En. *s*
	5·1	Di. *s*		15·1	Te. *n*		18·2	Mi. *n*
	6·0	En. *n*		18·9	Di. *n*	3	1·6	Te. *n*
	9·3	Mi. *s*		19·4	Mi. *s*		5·5	Mi. *s*
	20·6	Mi. *n*		20·2	En. *n*		6·0	Rh. *n*
	22·5	En. *s*	24	5·3	Rh. *n*		8·7	Di. *s*
15	3·3	Te. *s*		6·7	Mi. *n*		10·3	En. *n*
	4·7	Rh. *n*		12·6	En. *s*		16·8	Mi. *n*
	7·9	Mi. *s*		13·8	Te. *s*	4	0·2	Te. *s*
	13·9	Di. *n*		18·0	Mi. *s*		2·8	En. *s*
	14·9	En. *n*	25	3·7	Di. *s*		4·2	Mi. *s*
	19·2	Mi. *n*		5·1	En. *n*		9·1	Rh. *e*
16	2·0	Te. *n*		5·3	Mi. *n*		15·5	Mi. *n*
	6·5	Mi. *s*		8·4	Rh. *e*		17·5	Di. *n*
	7·4	En. *s*		12·4	Te. *n*		19·2	En. *n*
	7·8	Rh. *e*		16·6	Mi. *s*		22·9	Te. *n*
	17·8	Mi. *n*		21·5	En. *s*	5	2·8	Mi. *s*
	22·8	Di. *s*	26	3·9	Mi. *n*		11·6	En. *s*
	23·8	En. *n*		11·1	Te. *s*		12·2	Rh. *s*
17	0·6	Te. *s*		11·5	Rh. *s*		14·1	Mi. *n*
	5·1	Mi. *s*		12·5	Di. *n*		21·5	Te. *s*
	10·9	Rh. *s*		13·9	En. *n*	6	1·4	Mi. *s*
	16·2	En. *s*		15·2	Mi. *s*		2·3	Di. *s*
	16·4	Mi. *n*	27	2·5	Mi. *n*		4·1	En. *s*
	23·3	Te. *n*		6·4	En. *s*		12·7	Mi. *n*
18	3·7	Mi. *s*		9·7	Te. *n*		15·3	Rh. *w*
	7·6	Di. *n*		13·9	Mi. *s*		20·2	Te. *n*
	8·7	En. *n*		14·6	Rh. *w*		20·5	En. *s*
	13·9	Rh. *w*		21·4	Di. *s*	7	0·0	Mi. *s*
	15·0	Mi. *n*		22·8	En. *n*		11·2	Di. *n*
	21·9	Te. *s*	28	1·2	Mi. *n*		11·3	Mi. *n*
19	1·1	En. *s*		8·4	Te. *s*		13·0	En. *n*
	2·3	Mi. *s*		12·5	Mi. *s*		18·4	Rh. *n*
	13·6	Mi. *n*		15·2	En. *s*		18·8	Te. *s*
	16·4	Di. *s*		17·7	Rh. *n*		22·6	Mi. *s*
	17·0	Rh. *n*		23·8	Mi. *n*	8	5·4	En. *s*
	17·5	En. *n*	29	6·2	Di. *n*		9·9	Mi. *n*
	20·6	Te. *n*		7·0	Te. *n*		17·5	Te. *n*
20	0·9	Mi. *s*		7·7	En. *n*		20·0	Di. *s*
	10·0	En. *s*		11·1	Mi. *s*		21·2	Mi. *s*
	12·2	Mi. *n*		20·8	Rh. *e*		21·4	Rh. *e*
	19·2	Te. *s*		22·4	Mi. *n*		21·8	En. *n*
	20·1	Rh. *e*	30	0·1	En. *s*	9	8·5	Mi. *n*
	23·6	Mi. *s*		5·7	Te. *s*		14·3	En. *s*
21	1·2	Di. *n*		9·7	Mi. *s*		16·1	Te. *s*
	2·4	En. *n*		15·0	Di. *s*		19·8	Mi. *s*
	10·9	Mi. *n*		16·6	En. *n*	10	0·5	Rh. *s*
	17·8	Te. *n*		21·0	Mi. *n*		4·8	Di. *n*
	18·9	En. *s*		23·8	Rh. *s*		6·7	En. *n*
	22·2	Mi. *s*	May 1	4·3	Te. *n*		7·2	Mi. *n*
	23·2	Rh. *s*		8·3	Mi. *s*		14·8	Te. *n*
22	9·5	Mi. *n*		9·0	En. *s*		18·5	Mi. *s*
	10·1	Di. *s*		19·6	Mi. *n*		23·2	En. *s*
	11·3	En. *n*		23·9	Di. *n*	11	3·6	Rh. *w*
	16·5	Te. *s*	2	1·4	En. *n*		5·8	Mi. *n*
	20·8	Mi. *s*		2·9	Rh. *w*		13·4	Te. *s*

1894.	G.M.T. h		
May	11	13·7	Di. *s*
		15·6	En. *n*
		17·1	Mi. *s*
	12	4·4	Mi. *n*
		6·7	Rh. *n*
		8·0	En. *s*
		12·1	Te. *n*
		15·7	Mi. *s*
		22·5	Di. *n*
	13	0·5	En. *n*
		3·0	Mi. *n*
		9·8	Rh. *e*
		10·7	Te. *s*
		14·3	Mi. *s*
		16·9	En. *s*
	14	1·6	Mi. *n*
		7·3	Di. *s*
		9·4	En. *n*
		9·4	Te. *n*
		12·9	Rh. *s*
		12·9	Mi. *s*
	15	0·2	Mi. *n*
		1·8	En. *s*
		8·0	Te. *s*
		11·5	Mi. *s*
		16·0	Rh. *w*
		16·2	Di. *n*
		18·2	En. *n*
		22·8	Mi. *n*
	16	6·7	Te. *n*
		10·2	Mi. *s*
		10·7	En. *s*
		19·1	Rh. *n*
		21·5	Mi. *n*
	17	1·0	Di. *s*
		3·1	En. *n*
		5·3	Te. *s*
		8·8	Mi. *s*
		19·6	En. *s*
		20·1	Mi. *n*
		22·1	Rh. *e*
	18	4·0	Te. *n*
		7·4	Mi. *s*
		9·8	Di. *n*
		12·0	En. *n*
		18·7	Mi. *n*
	19	1·2	Rh. *s*
		2·6	Te. *s*
		4·4	En. *s*
		6·0	Mi. *s*
		17·1	Mi. *n*
		18·6	Di. *s*
		20·9	En. *n*
	20	1·3	Te. *n*
		4·3	Rh. *w*
		4·6	Mi. *s*
		13·3	En. *s*
		15·9	Mi. *n*

1894.	G.M.T. h		
May	20	23·9	Te. *s*
	21	3·2	Mi. *s*
		3·5	Di. *n*
		5·8	En. *n*
		7·4	Rh. *n*
		14·5	Mi. *n*
		22·2	En. *s*
		22·6	Te. *n*
	22	1·9	Mi. *s*
		10·5	Rh. *e*
		12·3	Di. *s*
		13·2	Mi. *n*
		14·6	En. *n*
		21·2	Te. *s*
	23	0·5	Mi. *s*
		7·1	En. *s*
		11·8	Mi. *n*
		13·6	Rh. *s*
		19·9	Te. *n*
		21·1	Di. *n*
		23·1	Mi. *s*
		23·5	En. *n*
	24	10·4	Mi. *n*
		16·0	En. *s*
		16·7	Rh. *w*
		18·5	Te. *s*
		21·7	Mi. *s*
	25	6·0	Di. *s*
		8·4	En. *n*
		9·0	Mi. *n*
		17·2	Te. *n*
		19·8	Rh. *n*
		20·3	Mi. *s*
	26	0·8	En. *s*
		7·6	Mi. *n*
		14·8	Di. *n*
		15·8	Te. *s*
		17·3	En. *n*
		18·9	Mi. *s*
		22·9	Rh. *e*
	27	6·2	Mi. *n*
		9·7	En. *s*
		14·5	Te. *n*
		17·6	Mi. *s*
		23·7	Di. *s*
	28	2·0	Rh. *s*
		2·2	En. *n*
		4·9	Mi. *n*
		13·1	Te. *s*
		16·2	Mi. *s*
		18·6	En. *s*
	29	3·5	Mi. *n*
		5·1	Rh. *w*
		8·5	Di. *n*
		11·1	En. *n*
		11·8	Te. *n*
		14·8	Mi. *s*
	30	2·1	Mi. *n*

1894.	G.M.T. h		
May	30	3·5	En. *s*
		8·2	Rh. *n*
		10·4	Te. *s*
		13·4	Mi. *s*
		17·3	Di. *s*
		19·9	En. *n*
	31	0·7	Mi. *n*
		9·4	Te. *n*
		11·3	Rh. *e*
		12·0	Mi. *s*
		12·4	En. *s*
		23·3	Mi. *n*
June	1	2·2	Di. *n*
		4·8	En. *n*
		7·7	Te. *s*
		10·6	Mi. *s*
		14·4	Rh. *s*
		21·3	En. *s*
		21·9	Mi. *n*
	2	6·4	Te. *n*
		9·3	Mi. *s*
		11·0	Di. *s*
		13·7	En. *n*
		17·5	Rh. *w*
		20·6	Mi. *n*
	3	5·0	Te. *s*
		6·1	En. *s*
		7·9	Mi. *s*
		19·2	Mi. *n*
		19·8	Di. *n*
		20·6	Rh. *n*
		22·6	En. *n*
	4	3·7	Te. *n*
		6·5	Mi. *s*
		15·0	En. *s*
		17·8	Mi. *n*
		23·7	Rh. *e*
	5	2·3	Te. *s*
		4·7	Di. *n*
		5·1	Mi. *s*
		7·5	En. *n*
		16·4	Mi. *n*
		23·9	En. *s*
	6	1·0	Te. *n*
		2·8	Rh. *s*
		3·7	Mi. *s*
		13·5	Di. *n*
		15·0	Mi. *n*
		16·4	En. *n*
		23·6	Te. *s*
	7	2·3	Mi. *s*
		5·9	Rh. *w*
		8·8	En. *s*
		13·7	Mi. *n*
		22·3	Te. *n*
		22·4	Di. *s*
	8	1·0	Mi. *s*
		1·2	En. *n*

1894.	G.M.T. h		
June	8	9·0	Rh. *n*
		12·3	Mi. *n*
		17·7	En. *s*
		20·9	Te. *s*
		23·6	Mi. *s*
	9	7·2	Di. *n*
		10·1	En. *n*
		10·9	Mi. *n*
		12·1	Rh. *e*
		19·6	Te. *n*
		22·2	Mi. *s*
	10	2·6	En. *s*
		9·5	Mi. *n*
		15·2	Rh. *s*
		16·0	Di. *s*
		18·3	Te. *s*
		19·0	En. *n*
		20·8	Mi. *s*
	11	8·1	Mi. *n*
		11·5	En. *s*
		16·9	Te. *n*
		18·3	Rh. *w*
		19·4	Mi. *s*
	12	0·9	Di. *n*
		3·9	En. *n*
		6·7	Mi. *n*
		15·6	Te. *s*
		18·1	Mi. *s*
		20·3	En. *s*
		21·4	Rh. *n*
	13	5·4	Mi. *n*
		9·7	Di. *s*
		12·8	En. *n*
		14·2	Te. *n*
		16·7	Mi. *s*
	14	0·5	Rh. *e*
		4·0	Mi. *n*
		5·2	En. *s*
		12·9	Te. *s*
		15·3	Mi. *s*
		18·6	Di. *n*
		21·7	En. *n*
	15	2·6	Mi. *n*
		3·6	Rh. *s*
		11·5	Te. *n*
		13·9	Mi. *s*
		14·1	En. *s*
	16	1·2	Mi. *n*
		3·4	Di. *s*
		6·6	En. *n*
		6·7	Rh. *w*
		10·2	Te. *s*
		12·5	Mi. *s*

1894.	G.M.T. h		
June	16	23·0	En. *s*
		23·8	Mi. *n*
	17	8·8	Te. *n*
		9·8	Rh. *n*
		11·1	Mi. *s*
		12·3	Di. *n*
		15·4	En. *n*
		22·5	Mi. *n*
		Transit of Mercury.	
	18	7·5	Te. *s*
		7·9	En. *s*
		9·8	Mi. *s*
		12·9	Rh. *e*
		21·1	Mi. *n*
		21·1	Di. *s*
	19	0·3	En. *n*
		6·1	Te. *n*
		8·4	Mi. *s*
		16·0	Rh. *s*
		16·8	En. *s*
		19·7	Mi. *n*
	20	4·8	Te. *s*
		5·9	Di. *n*
		7·0	Mi. *s*
		9·2	En. *n*
		18·3	Mi. *n*
		19·1	Rh. *w*
	21	1·7	En. *s*
		3·5	Te. *n*
		5·6	Mi. *s*
		14·8	Di. *s*
		16·9	Mi. *n*
		18·1	En. *n*
		22·2	Rh. *n*
	22	2·1	Te. *s*
		4·2	Mi. *s*
		10·6	En. *s*
		15·6	Mi. *n*
		23·6	Di. *n*
	23	0·8	Te. *n*
		1·3	Rh. *e*
		2·9	Mi. *s*
		3·0	En. *n*
		14·2	Mi. *n*
		19·4	En. *s*
		23·4	Te. *s*
	24	1·5	Mi. *s*
		4·4	Rh. *s*
		8·5	Di. *s*
		11·9	En. *n*
		12·8	Mi. *n*
		22·1	Te. *n*

1894.	G.M.T. h		
June	25	0·1	Mi. *s*
		4·3	En. *s*
		7·5	Rh. *w*
		11·4	Mi. *n*
		17·3	Di. *n*
		20·7	Te. *s*
		20·8	En. *n*
		22·7	Mi. *s*
	26	10·0	Mi. *n*
		10·6	Rh. *n*
		13·2	En. *s*
		19·4	Te. *n*
		21·3	Mi. *s*
	27	2·2	Di. *s*
		5·7	En. *n*
		8·7	Mi. *n*
		13·7	Rh. *e*
		18·0	Te. *s*
		20·0	Mi. *s*
		22·1	En *s*
	28	7·3	Mi. *n*
		11·0	Di. *n*
		14·6	En. *n*
		16·7	Te. *n*
		16·9	Rh. *s*
		18·6	Mi. *s*
	29	5·9	Mi. *n*
		7·0	En. *s*
		15·4	Te. *s*
		17·2	Mi. *s*
		19·9	Di. *s*
		20·0	Rh. *w*
		23·4	En. *n*
	30	4·5	Mi. *n*
		14·0	Te. *n*
		15·8	Mi. *s*
		15·9	En. *s*
		23·1	Rh. *n*
July	1	4·7	Di. *n*
		8·3	En. *n*
		12·7	Te. *s*
	2	2·2	Rh. *e*
		11·3	Te. *n*
		13·6	Di. *s*
	3	5·3	Rh. *s*
		10·0	Te. *s*
		22·4	Di. *n*
	4	8·4	Rh. *w*
		8·7	Te. *n*
	5	7·3	Di. *s*
		7·3	Te. *s*
		11·5	Rh. *n*

By means of this list of conjunctions approximate values of the rectangular co-ordinates x and y of the five satellites may be easily found for any other time t with the help of the following table, the argument of which is the interval τ of the time t and the time of the nearest preceding or following conjunction, the unit of x and y being the equatorial semi-diameter of the ball of *Saturn*. The satellites move in the direction of *in*creasing position-angles, and are in the interval between a north and a south conjunction on the following side, and between a south and a north conjunction on the preceding side of the direction of the polar axis of *Saturn*. They are at their greatest elongation *Mimas* about 5·7, *Enceladus* 8·2, *Tethys* 11·3, *Dione* 16·4, and *Rhea* about 27·1 hours before or after the times of their conjunctions with the centre.

	Mimas.		*Enceladus.*		*Tethys.*		*Dione.*		*Rhea.*	
τ	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4	x_5	y_5
0ʰ	0·0	0·7	0·0	0·9	0·0	1·1	0·0	1·4	0·0	2·0
1	0·9	0·7	0·8	0·9	0·7	1·1	0·6	1·4	0·5	2·0
2	1·7	0·6	1·5	0·8	1·4	1·1	1·2	1·4	1·0	2·0
3	2·3	0·5	2·2	0·7	2·0	1·0	1·8	1·4	1·5	1·9
4	2·8	0·3	2·8	0·6	2·6	0·9	2·4	1·3	2·0	1·9
5	3·1	0·1	3·3	0·5	3·2	0·8	2·9	1·3	2·5	1·9
6	3·1	0·1	3·7	0·4	3·7	0·7	3·5	1·2	3·0	1·8
7	2·9	0·3	3·9	0·2	4·1	0·6	4·0	1·1	3·5	1·8
8	2·5	0·4	4·0	0·0	4·5	0·5	4·4	1·0	4·0	1·8
9	1·8	0·6	4·0	0·1	4·7	0·4	4·8	0·9	4·5	1·7
10	1·1	0·7	3·8	0·3	4·9	0·2	5·2	0·8	4·9	1·6
11	...		...		5·0	0·0	5·5	0·7	5·3	1·6
12	...		...		...		5·8	0·6	5·7	1·5
16	...		...		...		6·4	0·1	7·1	1·2
20	...		...		...		...		8·2	0·8

Careful estimations of the times of the transits of the satellites across the prolonged polar axis of the ball are valuable for the determination of their orbital longitudes. *Mimas* and, after the end of March, also *Enceladus* are not observable at these times, as they are not outside the disc; their conjunctions with the ends of the ring take place about 3·0 and 3·2 hours before or after their conjunctions with the centre.

Ephemeris of the Satellites of Uranus, 1894. By A. Marth.

Greenwich Noon. 1894.	P	*Ariel.* a_1	b_1	u_1-U.	Diff.	*Umbriel.* a_2	b_2	u_2-U.	Diff.
	°	"	"	°	°	"	"	°	°
Mar. 2	272·36	14·56	+12·37	201·54	1428·40	20·29	+17·24	52·14	868·69
12	272·47	14·68	12·45	189·94	·34	20·45	17·35	200·83	·63
22	272·63	14·78	12·51	178·28	·30	20·60	17·43	349·46	·60
Apr. 1	272·83	14·87	12·54	166·58	·26	20·72	17·47	138·06	·57
11	273·06	14·94	12·55	154·84	·22	20·81	17·49	286·63	·54
21	273·31	14·98	12·53	143·06	·19	20·87	17·46	75·17	·52
May 1	273·57	15·00	+12·49	131·25	·17	20·90	+17·40	223·69	·51
11	273·83	15·00	12·43	119·42	·16	20·89	17·31	12·20	·50
21	274·08	14·97	12·34	107·58	·15	20·85	17·19	160·70	·50
31	274·30	14·91	12·24	95·73	·15	20·77	17·06	309·20	·51
June 10	274·48	14·83	12·13	83·88	·16	20·67	16·90	97·71	·53
20	274·63	14·74	12·02	72·04	1428·18	20·54	16·74	246·24	868·55
30	274·75	14·63	+11·90	60·22		20·38	+16·58	34·79	

	Titania. a_3	b_3	u_3-U	Diff.	*Oberon.* a_4	b_4	u_4-U	U	B
	"	"	°	°	"	"	°	°	°
Mar. 2	33·28	+28·27	244·83	413·48	44·50	+37·81	302·16	353·34	+58·16
12	33·55	28·46	298·31	·44	44·86	38·05	209·50	353·42	58·01
22	33·78	28·59	351·75	·40	45·18	38·23	116·80	353·53	57·79
Apr. 1	33·98	28·66	45·15	·37	45·45	38·33	24·07	353·67	57·50
11	34·14	28·68	98·52	·35	45·65	38·35	291·32	353·83	57·16
21	34·24	28·64	151·87	·33	45·79	38·30	198·55	354·01	56·78
May 1	34·28	+28·54	205·20	·33	45·85	+38·17	105·76	354·19	+56·37
11	34·27	28·40	258·53	·34	45·83	37·97	12·98	354·37	55·96
21	34·20	28·20	311·87	·35	45·73	37·72	280·20	354·53	55·56
31	34·07	27·98	5·22	·36	45·56	37·41	187·43	354·68	55·19
June 10	33·90	27·73	58·58	·39	45·33	37·07	94·68	354·81	54·87
20	33·68	27·46	111·97	413·41	45·05	36·72	1·96	354·91	54·61
30	33·43	+27·19	165·38		44·71	+36·36	269·26	354·99	+54·41

The values of P, a, b, and $u-U$ being interpolated for the times for which the apparent positions of the satellites are required, the position-angles p and distances s from the centre of the planet are found by means of the formulæ :

$$s \sin (p-P) = a \sin (u-U)$$
$$s \cos (p-P) = b \cos (u-U)$$

Since the Earth passed through the planes of the orbits in 1882, the only observations of the inner satellites which have come to my knowledge are the few measures, published in vol. iv. pp. 340, 341 of the *Bulletin Astronomique*, made by M. Perrotin in 1887, at a time when the apparent orbits were still too narrow to allow the satellites to be observed except not far from their greatest elongations or digressions. The apparent orbits are now sufficiently opened to allow the satellites to be seen in any part, and it is high time that good measures should be secured, before *Uranus* gets too far south for exact observing in northern latitudes. Cannot observers with powerful instruments be induced to contribute at least some good position-angles of the satellites during the present opposition?

A sidereal revolution of *Uranus* being performed in approximately 84 sidereal years, the apparent positions of the planet with regard to fixed stars recur very nearly after that period, so that the apparent path of *Uranus* during the present apparition differs only slightly from what it was in 1810. In the Berlin *Jahrbuch* for 1814 Bode represents in fig. 2 of the plate the path of the planet from 1810 April 26 to May 5, when it was near the stars 8 and 9 *a Libræ* (the 1 *a* and 2 *a Libræ* of Maskelyne's fundamental catalogue). On p. 167 Bode mentions that on April 29 he compared *Uranus* with 1 *a Libræ*, and found it just as bright, only somewhat paler.

Note on the Transit of Mercury over the Sun's Disc, which takes place for Venus on 1894 March 21, and on the Transits of Venus and Mercury, which occur for Saturn's System on the same day. By A. Marth.

After an interval of thirty years, during which no transit of *Mercury* across the Sun has occurred for *Venus*, the first of a new group of transits takes place on March 21. The centre of *Mercury's* disc (of 20″·3 apparent diameter) will enter upon the Sun's disc (of 1333″·7 semi-diameter) for the centre of *Venus* at $10^h\ 48^m$ G. M. T. in pos. angle 21° (reckoned from the circle of ecliptical latitude), and will leave it at $14^h\ 30^m$ in pos. 319°, the difference of the parallaxes being 16″·4, which data will be sufficient for a graphical representation.

Some hours before this transit both planets will have crossed the Sun's disc for *Saturn's* system, *Venus* entering as a spot of 2″·0 diameter for *Saturn's* centre on March 20 at $18^h\ 50^m$ G. M. T. in pos. angle 34°, and leaving it on March 21 at $0^h\ 56^m$ in pos. 322°; while *Mercury*, a tiny spot of only 0″·7 diameter, enters at $5^h\ 9^m$ in pos. 11°, and leaves at $7^h\ 41^m$ in pos. 337°, the apparent semi-diameter of the Sun's disc being 99″·2.

The following is a list of the transits of the planets since 1830:

Transits of Mercury for Venus.

	Helioc. Longit.
	°
1843 Feb. 28·7	203·4
1847 Feb. 27·8	21·5
1848 Sept. 13·9	206·9
1852 Sept. 12·5	23·8
1858 Mar. 29·2	26·1
1863 Oct. 12·9	28·5
1894 Mar. 21·5	202·2

Transits of Venus for Saturn.

1835 Oct.	13·4	205·9
1836 May	30·0	213·2
1851 June	22·8	26·5
1852 Feb.	7·6	34·6
1864 Sept.	7·7	199·9
1865 Apr.	25·0	207·3
Dec.	10·2	214·6
1880 May	17·5	20·1
1881 Jan.	2·2	28·2
Aug.	20·0	36·3
1894 Mar.	20·9	201·1
Nov.	5·2	208·5
1895 June	22·4	215·8

Transits of Mercury for Saturn.

	Helioc. Longit.	
	°	°
1835 June	15·2	202·0
Sept.	12·0	204·8
Dec.	9·9	207·7
1836 Mar.	7·7	210·5
1851 Jan.	5·2	20·6
Apr.	3·7	23·6
July	1·2	26·8
Sept.	27·7	29 9
Dec.	25·3	33·0
1864 Nov.	1·2	201·6
1865 Jan.	29·0	204·5
Apr.	27 9	207·4
July	25·8	210·2
1880 May	24·3	20·4
Aug.	20·8	23·4
Nov.	17·3	26·6
1881 Feb.	13·9	29·7
May	13·3	32·8
1894 Mar.	21·3	201·2
June	18·0	204·0
Sept.	14·9	206·9
Dec.	12·7	209·7

Some hours before the occurrence of the transit of *Mercury* for the dayside of *Venus* on March 21, the nightside of the planet is favoured by another phenomenon of some interest—a partial eclipse of the satellite of the Earth. For those readers who may like to form some clear notions of the apparent positions of the Moon as seen from *Venus*, the following short ephemeris of the polar and rectangular co-ordinates of the Moon, referred to the Earth and its axis, may serve for a graphical representation:

Greenwich Noon. 1894.	*s*	*p*	*x*	*y*	D	*d*
	″	°	″	″	″	″
Mar. 18	235·3	355·5	− 18·4	+234·6	45·3	12·3
19	289·6	67·9	+ 268·4	+109·0	44·6	12·1
20	531·2	92·1	530·9	− 19·5	43·9	11·9
21	769·8	100·7	756·4	143·4	43·1	11·7
22	970·1	105·3	935·7	256·0	42·4	11·5
23	1119·5	108·3	1062·8	351·8	41·8	11·4
24	1213·0	110·6	+1135·3	−427·0	41·1	11·2

D and *d* are the apparent diameters of the Earth and Moon, their greatest defects of illumination on March 21 being 4″·7 and 1″·3 in position-angle 106°.

The corresponding data for the Moon's position, as seen from *Mercury*, are:

Greenwich Noon. 1894.	*s*	*p*	*x*	*y*	D	*d*
	″	°	″	″	″	″
Mar. 18	459·0	305·2	−375·2	+264·4	29·1	7·9
19	263·9	311·6	192·6	175·5	29·0	7·9
20	76·3	354·0	− 8·0	+ 75·9	28·8	7·8
21	180·3	98·5	+178·6	− 26·7	28·6	7·8
22	371·5	109·7	349·8	125·1	28·3	7·7
23	540·2	113·2	496·5	212·8	28·0	7·6
24	674·7	115·1	+611·5	−285·2	27·6	7·5

The greatest defects of illumination on March 21 are 0″·4 and 0″·1 in position-angle 104.°.

But *Mercury* is favoured at the same time by a grander sight —the aspect of brilliant *Venus* near *Saturn*. On March 21, at $14^h·3$ G. M. T., *Venus* comes within one degree of *Saturn*, approaches it most closely on March 22 at $16^h·5$, at a distance of 25′, and reaches again the distance of one degree on March 23 at $18^h·8$. The apparent motions of both planets are retrograde, the conjunction being the middle one of three conjunctions occurring during the same synodical revolution. While, during this second conjunction, *Saturn* will appear for *Mercury* of about the brightness which it will have for the Earth in the middle of June, *Venus*, with an apparent diameter of 57″ or more, will appear for *Mercury* eight times as brilliant as it appears to the Earth when at its greatest brilliancy: this occurs just at the same time.

Col. Cooper's Observatory:
Markree, Collooney, Ireland.

Second List of Corrections of "Galactic Longitudes and Latitudes" in vol. liii. By A. Marth.

Vol. 53, p. 384	182°·26 − 1°·37 lat. should be	−0°·37
385	187·46 − 2·28 „ „	−2·88
387	199·77 + 6·16 should be	199·96 + 5·48
„	201·04 − 9·35 „ „	201·19 − 8·99
389	208·86 − 4·99 long. should be 203·86, so that the position ought to have been inserted on the preceding page	
394	235·08 − 6·31 should be	234·66 − 6·81
„	237·90 − 78·89 lat. should be	−7·89
406	300·40 + 10·74 „ „	−10·74
409	319·09 − 12·93 „ „	+12·93
414	347·80 − 9·46 long. „	347·20

Mr. Ant. Pannekoek, of Leiden, has been good enough to comply with my request on page 420, and has pointed out these errors, except the fourth, for which I have to thank Professor J. de Moraes Pereira, of S. Miguel, Azores, who had also remarked the fifth error.

Erratum in Mr. Jacoby's paper on 61 *Cygni*, in *Monthly Notices*, vol. liv., p. 117, line 21 from bottom:

for such *read* each.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. FEBRUARY 9, 1894. No. 4

CAPTAIN W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

William Ford Stanley, F.G.S., F.R.Met. Soc., Cumberlow, South Norwood,

was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Lyndon Bolton, B.A. (Cantab.), Patent Office, Southampton Buildings, W.C. (proposed by Harold Seward);

F. W. Dyson, Fellow of Trinity College, Cambridge (proposed by H. H. Turner);

G. P. Jenkins, National Provincial Bank, Llangefni, Anglesea (proposed by G. H. With);

W. Redfern Kelly, Mem. Inst. C.E., Dalriada, Malone Park, Belfast (proposed by Major Somerset H. Maxwell).

Report of the Council to the Seventy-fourth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1892	244	373	1	618	48	1	667
Since elected	+4	+32	...	...	...	...	...
Deceased	−2	− 8	...	...	−2	...	...
Resigned	...	− 7	...	...	...	...	...
Removals	+3	− 3	...	...	...	...	...
Expelled	...	− 1	...	...	...	...	...
December 31, 1893	249	386	1	636	46	1	683

Dr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1893 January 1:—						
At Bankers', as per Pass Book	163	16	0			
Country cheques not credited till 1893 ...	8	8	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	10	4	6			
In hand of Assistant Secretary on Petty Cash Account	1	3	5			
				183	11	11
Dividends on £13,200 Consols, 2¾ per cent. ...	353	3	8			
„ on £650 New 2½-per-cent. Stock ...	15	16	4			
„ on £1,250 Metropolitan 3-per-cent. Stock	36	9	0			
				405	9	0
Received on account of Subscriptions:—						
Arrears	132	6	0			
248 Annual Contributions for 1893	520	16	0			
5 „ „ 1894	10	10	0			
Admission Fees	86	2	0			
First Contributions	56	14	0			
				806	8	0
8 Composition Fees				168	0	0
Sales of Publications:—						
At Williams & Norgate's, 1892	37	11	6.			
At Society's Rooms, 1893	47	4	3			
				84	15	9
Income Tax for the last 3 years, refunded by the Commissioners of Inland Revenue				61	6	10

Audited and found correct, 1894 January 10.

W. B. Gibbs,
Arthur Cottam,
Richard Inwards.

£1,709 11 6

Astronomical Society, from 1893 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
„ „ for assistance in editing Society's Publications ..	50	0	0			
				300	0	0
House Duty	2	12	6			
Fire Insurance	7	16	6			
				10	9	0
Printing, &c.	425	3	6			
Lithography, Engraving, &c.	43	2	0			
				468	5	6
Turnor and Horrox Fund: Purchases for Library	9	2	3			
Binding Books in Library	32	13	2			
				41	15	5
Photographs for Chicago Exhibition				28	0	6
Eclipse Expeditions: purchase of Instruments ...	41	0	0			
Balance of Expenses of Expeditions	100	0	0			
				141	0	0
Wages	46	18	0			
Postage	64	2	4			
Carriage of Parcels	2	10	4			
Stationery and Office Expenses	6	14	4			
				120	5	0
Expenses of Meetings	20	0	0			
Lantern Expenses	4	3	3			
				24	3	3
House Expenses	58	13	0			
Coals and Gas	55	1	8			
Electric Light Expenses	14	10	11			
Rental of Wire for Time Signal	5	0	0			
Fittings and Repairs	24	4	7			
Sundries	9	3	4			
				166	13	6
Lee and Janson Fund Grants	22	10	0			
Mrs. Jackson Gwilt's Annuity	8	19	0			
				31	9	0
Cheque Book	0	8	4			
Bankers' deductions on cheques	0	2	6			
				0	10	10
Balances, 1893 December 30:—						
At Bankers', as per Pass Book	365	15	11			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	11	2	3			
In hand of Assistant Secretary on Petty Cash Account	0	1	4			
				376	19	6
				£1,709	11	6

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1893, and have found and certified the same to be correct. The cash in hand on 1893 December 30, including the balance at the bankers', &c., amounted to £376 19*s.* 6*d.*

The funded property of the Society is the same as at the end of last year.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(Signed) W. B. GIBBS,
ARTHUR COTTAM,
RICHARD INWARDS.

January 10, 1894.

Trust Funds.

The Turnor Fund: A sum of £450 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £100 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £323 16*s.* 3*d.* 2¾-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

Assets and Present Property of the Society, 1894 January 1.

	£	s.	d.	£	s.	d.
Balances, 1893 December 30:—						
At Bankers'	365	15	11			
In hand of Assistant Secretary on account of Turnor and Horrox Funds	11	2	3			
In hand of Assistant Secretary on Petty Cash Account	0	1	4			
				376	19	6
Due on account of Subscriptions:—						
5 Contributions of 4 years' standing... ...	42	0	0			
13 „ 3 „	81	18	0			
29 „ 2 „	121	16	0			
64 „ 1 „	134	8	0			
Admission Fees, &c.	7	7	0			
Other Amounts	9	9	0			
	396	18	0			
Less 5 Contributions paid in advance ...	10	10	0			
				386	8	0
Due from Messrs. Williams & Norgate for sales of Publications during 1893				14	19	3

£13,200 2¾-per-cent. Consols, including the Lee and Janson Fund, the Turnor Fund, the Horrox Memorial Fund, and Mrs. Jackson Gwilt's gift.

£650 New 2½-per-cent. Consols.

£1,250 Metropolitan 3-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments; Furniture, &c.

Unsold Publications of the Society.

3 Gold Medals.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	156	...
I. Part 2	42	...	XXXI.	139	...
II. Part 1	51	3	XXXII.	151	...
II. Part 2	17	3	XXXIII.	159	1
III. Part 1	65	...	XXXIV.	162	3
III. Part 2	84	...	XXXV.	107	4
IV. Part 1	77	3	XXXVI.	190	8
IV. Part 2	90	3	XXXVII. Part 1	335	8
V.	102	3	XXXVII. Part 2	281	8
VI.	120	6	XXXVIII.	266	1
VII.	142		XXXIX. Part 1	234	3
VIII.	126	3	XXXIX. Part 2	239	3
IX.	133	3	XL.	257	1
X.	143	...	XLI.	406	1
XI.	152	...	XLII.	231	3
XII.	159	...	XLIII.	234	1
XIII.	158	...	XLIV.	213	1
XIV.	361	...	XLV.	246	...
XV.	137	...	XLVI.	226	3
XVI.	163	1	XLVII. Part 1	3	...
XVII.	146	1	XLVII. Part 2	18	...
XVIII.	138	1	XLVII. Part 3	2	...
XIX.	145	1	XLVII. Part 4	10	...
XX.	139	1	XLVII. Part 5	8	...
XXI. Part 1	310	...	XLVII. Part 6	9	...
XXI. Part 2	98	...	XLVII.	199	2
XXI. 1 & 2 (together)	59	1	XLVIII. Part 1	244	1
XXII.	161	1	XLVIII. Part 2	249	1
XXIII.	145	1	XLIX. Part 1	422	1
XXIV.	148	1	XLIX. Part 2	270	1
XXV.	163	...	L.	317	1
XXVI.	169	1	Index to *Memoirs*	635	1
XXVII.	421	1			
XXVIII.	380	...			
XXIX.	402	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	60	...	XXVIII.	71	...
II.	62	...	XXIX.	51	...
III.	...	...	XXX.	64	2
IV.	...	...	XXXI.	92	...
V.	...	...	XXXII.	113	5
VI.	47	...	XXXIII.	95	...
VII.	2	...	XXXIV.	67	1
VIII.	153	2	XXXV.	57	...
IX.	24	3	XXXVI.	28	1
X.	172	1	XXXVII.	35	3
XI.	184	...	XXXVIII.	98	2
XII.	106	2	XXXIX.	95	1
XIII.	178	2	XL.	108	3
XIV.	177	3	XLI.	108	5
XV.	169	2	XLII.	117	1
XVI.	154	2	XLIII.	114	2
XVII.	167	1	XLIV.	119	2
XVIII.	244	...	XLV.	119	1
XIX.	54	...	XLVI.	114	...
XX.	34	...	XLVII.	132	2
XXI.	17	...	XLVIII.	124	1
XXII.	33	...	XLIX.	118	9
XXIII.	19	...	L.	120	11
XXIV.	24	...	LI.	122	11
XXV.	15	...	LII.	120	13
XXVI.	10	1	LIII.	122	19
XXVII.	3	...	Index ...	562	3
LIBRARY CATALOGUE				568	3

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LIII., no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes
The *Sheepshanks* collection:—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.
„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

No. 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

No. 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.
„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.
„ 47. (21) Box sextant; reflecting plane and level.
„ 48. (22) Prismatic compass, by Troughton and Simms.
„ 49. (23) Mountain barometer.
„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
„ 51. (25) Ordinary 4½-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.

No. 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.
„ 91. Astronomical time watchcase, by Professor Chevallier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.

No. 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 116. A pair of 18-inch globes.
„ 117, 118. Two old sun-dials.
„ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and refigured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-in. portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere, presented by Prof. Slater.
„ 130. 10-inch brass pillar sextant, by Troughton, presented by Dr. Nevins as executor of the late Mr. A. E. Nevins.
„ 131. Double box sextant, by Cary, presented by Dr. Nevins as executor of the late Mr. A. E. Nevins.

Besides the above, there is the following apparatus available for Eclipse work:—

4 Slits for Spectroscope.
2 Abney lenses used in photographing the Corona.
2 Dallmeyer negative enlarging lenses.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 10. Variation transit, to Mr. Maxwell Hall.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 22. The *Matthew* equatorial, to Mr. J. Brett.

No. 23. The *Matthew* transit, to Captain W. Noble.
„ 28. (2) 6-inch theodolite and stand, to Capt. D. Forbes.
„ 29. (3) Wire micrometer (No. 1), to Mr. C. Thwaites.
„ „ „ Wire micrometer (No. 2), to Mr. Maxwell Hall.
„ 30. (4) 3¼-inch equatorial and stand, to Mr. E. B. Powell.
„ „ „ Double-image micrometer, to Mr. Maxwell Hall.
„ 31. (5) 2⅞-inch telescope and stand, to Mr. F. J. Wardale.
„ 36. (10) 8-inch sextant, to Mr. C. H. Johns.
„ 38. (12) 18-inch *Borda* repeating circle, to Mr. Maxwell Hall.
„ 39. (13) 8-inch repeating circle, to Mr. J. Norman Lockyer.
„ 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. C. Thwaites.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.
„ 52. (26) Dipping needle, to Mr. Maxwell Hall.
„ 54. (28) Magnetic intensity needle, to Mr. Maxwell Hall.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„ 76. 5-prism direct vision hand Spectroscope, to Mr. E. B. Knobel.
„ 78. 9½-inch reflector and stand, to Mr. Maxwell Hall.
„ 79. Spectroscope, to Mr. Maxwell Hall.
„ 85. Double-image micrometer, to Mr. B. T. Moore.
„ 99. 12-inch portable transit instrument, to Mr. H. T. Vivian.
„ 120. 6-prism spectroscope, by Browning, to Mr. C. Thwaites.
„ 123. 6-inch refractor, by Grubb (object-glass only), to Mr. W. E. Wilson.
„ 124. Position micrometer, by Cooke, to the Rev. A. Freeman.
„ 126. 3½-inch portable refractor, by Tulley, to Mr. H. Sadler.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Mr. S. W. Burnham for his discoveries and measurements of Double Stars.

Publications of the Society.

Volume LI., parts I. and II. of the *Memoirs* have been published during the past year; they contain the following papers:—

"On the investigation of the division errors of the scales of the Cape Repsold Measuring Apparatus, and the determination of the errors of the Oxford *Réseau*." By David Gill.

"The Spectrum of Nova *Aurigæ*." By the Rev. W. Sidgreaves.

"Physical Observations of *Mars*, made at the Allegheny Observatory in 1892." By J. E. Keeler.

The attention of foreign and American astronomers is requested to the following paragraph in the Report of the Council for 1879. It is against the rules of the Society to print any paper previously published:—

"The Council hope that the communication between English and foreign astronomers will continue to increase, but they take this opportunity of mentioning that some of the papers which have been received by the Society have not been printed on account of their having been previously published abroad."

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Rev. Daniel Ace.
John Derby Allcroft.
Charles Barton.
Vincent Fasel.
Arthur Edward Nevins.
Francis H. S. Orpen.
Major-Gen. Henry Spencer Palmer.
Rev. Charles Pritchard.
John Spencer.
Wesley S. B. Woolhouse.

Associates :—Rudolf Wolf.
Baron Fabian Jacob Wrede.

The Rev. Daniel Ace, D.D., was born at Devonport on 1813 February 6. He graduated at St. John's College, Cambridge, as B.D. in 1861, and received the degree of D.D. from both the Universities of Cambridge and Oxford. After holding several curacies, Dr. Ace was in 1871 appointed Vicar of Laughton-cum-Wildsworth, in Lincolnshire, and retained this position till his death on 1893 August 27. He was twice married. He was elected a Fellow on 1879 June 13, but did not contribute any papers to the Society.

John Derby Allcroft was born at Worcester on 1822 July 19, and at the age of sixteen was taken into his father's business, as glove manufacturer. He sat from 1877–1880 as Conservative member for Worcester, and was High Sheriff of Shropshire at the time of his death on 1893 July 29. He was twice married. He was elected a Fellow on 1865 January 13, but contributed no papers to the Society.

Charles Barton was born in 1841, and in 1856 was appointed one of the assistant masters at the Royal Hospital School, Greenwich. He was there so successful as a teacher of navigation that in 1861, at the early age of 20, he was appointed head-master of

the school-ship *Conway* at Liverpool, an institution founded in 1859 for the training of officers in the mercantile marine. He retained this position till his death, on 1892 September 13. The Committee of Management of the *Conway*, in appreciation of his sterling merit and valuable services, have founded in his memory a scholarship to be called the "Charles Barton Scholarship." He was elected a Fellow on 1869 March 12, but did not contribute any papers to the Society.

VINCENT FASEL was born on 1816 February 21, at Vuissens, Canton de Fribourg, Switzerland. His father, a physician, died when he was quite young. He was intended for the Roman Catholic priesthood, and was at the College of Estavayer from 1831 to 1834, and at the Grand Seminaire de Lyon in 1835 and 1836. He then visited Paris, Versailles, and arrived in London in 1841. About this time he gave up all thoughts of the priesthood and turned Protestant, and soon after went to Canada, where he remained from 1841 to 1846. On his return to England he was at the Stone Observatory, Hartwell, from 1847 to 1853, and at the Clapham Observatory from 1856 to 1869. He accompanied the late Professor Pritchard to Spain, on the Himalaya Eclipse Expedition of 1860. He was elected a Fellow on 1849 March 9, and contributed several papers to the Society, on Meteors (he observed the great shower of 1872 November 27) and the Zodiacal Light; but these were chiefly after he had given up official scientific work on account of his health, and had retired to Morges in 1869, where he lived till 1881. The remainder of his life he spent at Bex, Canton de Vaud, where his widow is now living.

ALBERT EDWARD NEVINS, son of Dr. Birkbeck Nevins, early adopted a sea life. During a voyage in the *Tenasserim* from Liverpool to Calcutta, he interested himself in the study of the rates of the chronometers in connection with Hartnup's formulæ. The results are embodied in a paper published in the *Monthly Notices*, 1874 December, and a second paper in vol. xxxix. gives the particulars for the return voyage. He appears thus to have been one of the first officers to give Hartnup's method an intelligent trial. In 1876 April, in a paper read before the Literary and Philosophical Society of Liverpool, he gave some very useful tables which considerably shortened the calculations in the application of Hartnup's formulæ. He did not confine his attention to chronometers, but devoted himself to the study of nautical astronomy, navigation, and meteorology as bearing on his profession. In 1879 he read a paper before the Liverpool Society on "Modern Meteorology considered in its bearing upon Tropical Storms."

Shortly afterwards, finding the sea life uncongenial, he retired and qualified himself for the medical profession, which he eventually practised until his death in 1893 April.

FRANCIS HENRY SAMUEL ORPEN, J.P., of St. Clair, near Douglas Division of Herbert Colony, of the Cape Colony, F.R.A.S. and F.R.G.S., born 1824 October 22, eldest son of the Rev. Dr. Charles Edward Herbert Orpen, M.D., member of various literary societies, the philanthropic founder of the National Deaf and Dumb Institution at Claremont, near Dublin. (For lineage, *vide* Burke's *Landed Gentry*.)

Mr. F. H. S. Orpen married Sarah Anne, eldest daughter of Alexander Hugh Murray, Esq., of Colesberg, Cape Colony, and leaves a surviving family of four sons and three daughters.

Mr. F. H. S. Orpen was educated at Trinity College, Dublin. Member of the Commission of Land Surveyors for the survey of the Orange River Sovereignty (now the Orange Free State), 1850 June. Entered the service of the native chief, U. Waterboer, as surveyor-general and civil commissioner of Albania, 1867 September 14; and on the cession of the province of Griqualand West to the British Government was appointed civil commissioner and resident magistrate of the Division of Griquatoria, with charge of the Survey Department of the province, 1871. Appointed surveyor-general of Griqualand West, 1872 October 9; commissioner for investigating and defining native claims to land, 1875 January to June, and 1876 October and November. Commissioner for defining native locations and investigating land claims, 1877 February to June. Acting registrar of deeds, 1878 June to 1879 March. Inspector-general of schools, 1879 January to December; retired on pension 1881 January 13, in consequence of the annexation of the province of Griqualand West to the colony of the Cape of Good Hope, and was at once elected to represent the Division of Barkly West in the Cape Legislative Assembly, 1881. He was elected as the first President of the South African Institution of Civil Engineers, Surveyors, and Architects.

The decease of this well-known colonist on 1893 February 22, took everyone by surprise, and was learnt with universal regret. The surveys which he undertook in the Divisions of Colesberg, Albany, Queenstown, Albert, and other Divisions, made him so well known on the frontier that he was welcomed everywhere; his friends numbered all the best-known and worthiest of the inhabitants of the Colony, from the several governors, generals, and executive officers downwards, for the last forty-eight years.

During the whole of his colonial life he was engaged in scientific pursuits, principally astronomical and geological; in the former, since he took a special interest in connection with the survey of the Colony.

Mr. F. H. S. Orpen took the greatest interest in the observations connected with the transit of *Venus*. He also placed his instruments at the service of Dr. Elkin when that astronomer visited Kimberley, and thus enabled him to obtain the first accurate determination of the longitude of that place. D. G.

Major-General HENRY SPENCER PALMER, R.E., was born at Bangalore, East Indies, on 1838 April 30. He was the third son of Colonel John Freke Palmer, of the Madras Staff Corps, and nephew of Sir Henry James, R.E., F.R.S., formerly Director-General of the Ordnance Survey of Great Britain. He entered the Royal Military Academy in 1856 January, and his lieutenant's commission in the Royal Engineers was dated 1856 December 20. In 1858 September he was appointed to the British Columbian Expedition, and remained with the Expedition till its close in 1863, being actively engaged in making surveys and explorations, some of them of considerable extent. On his return to England in 1864, Lieutenant Palmer was appointed to the Ordnance Survey, proceeding to Tonbridge, Kent, from which place as headquarters he conducted the survey of Kent and East Sussex, and parts of Berks and Bucks. He received his captaincy in 1866, and in 1867 was appointed Assistant Commissioner in the Parliamentary Boundaries Commission.

About this time he was actively engaged with his friend the late Rev. Pierce Butler, of Ulcombe Rectory, Kent, in setting on foot that project of a survey of the Sinaitic peninsula which ultimately—though checked for a time by the sudden death of Mr. Butler—was brought to such a successful issue, and of which the circumstances and results are so well known that it is not necessary to do more than refer to them here. To the magnificent volumes (published by the authority of the Treasury) which were the fruits of that expedition, Captain Palmer contributed largely—some two-fifths of the descriptive matter, together with the computation of the astronomical and other work of the survey, the drawing of several of the maps and plans, and the part editing of the whole work, having fallen to his share.

After returning home from Sinai in 1869 May, Captain Palmer was often called upon to speak and lecture on the subject; and in the next two or three years he thus addressed several important meetings, such as those at the University of Cambridge in 1870, the Church Congress in 1870, and the Archæological Congress in 1872.

In 1873 he was recommended to the Astronomer Royal by Admiral G. H. Richards, then Hydrographer to the Admiralty, for a chief astronomership in the enterprise for observing the transit of Venus. Sir George Airy soon afterwards nominated him as chief of the New Zealand party, a nomination approved by the Admiralty. On this service, after a course of practical preparation at the Royal Observatory, during which he gained the full confidence of Sir George Airy, he left England in 1874 June, accompanied by Lieutenant Darwin, R.E., and Lieutenant Crawford, R.N., as his assistants, and three non-commissioned officers of Engineers as trained practical photographers. (After arrival in New Zealand, this party was strengthened by the addition of Lieutenant Praed, R.N.) He was now Major,

having been promoted to that rank in 1873 December. He resigned his appointment on the Ordnance Survey on 1874 May 31, after being held for 10¼ years.

For his exertions and achievements in New Zealand, Major Palmer was very highly praised by the Astronomer Royal, who spoke of his "arrangements for establishing his own station, and for organising the whole country into an assembly of observers," as having been "most admirable, and worthy to be taken as a model in the future" (see Report to the Board of Visitors, 1875); and, later, of his "extensive preparations," as having been "made with the greatest skill and judgment." The weather was so cloudy in New Zealand at the critical phases of the transit, on December 9, that, though every phenomenon that could be seen was carefully observed and noted by Major Palmer, he believed and reported that his observations were valueless. An agreeable surprise, however, awaited him. In 1877, after the eye-observations at all the stations had been reduced and compared, it was found that Major Palmer's, instead of being worth nothing, gave a result of great value, being, in fact, almost identical with the mean derived from the rest of the observers at the other stations; in short, that, as Sir G. Airy remarked, the "preliminary phenomena," which it was found were most to be relied upon, had been "very well observed by him."

Before leaving New Zealand, Major Palmer, at the request of the Governor, the Marquis of Normanby, undertook an investigation of the provincial surveys throughout the Colony, with the view of advising the Government as to the best means of evolving order out of the chaos that then existed, and of placing the whole future system on a uniform, intelligent, and scientific basis. Between three and four months were given to this work, at the end of which Major Palmer submitted a Blue Book Report embodying his results and recommendations, for which he was warmly thanked by the Government, and which was adopted as the guide to subsequent reforms.

After returning from New Zealand in 1879 June, Major Palmer worked for a few months under the Astronomer Royal, reducing his observations and preparing his report. Then, returning to corps duties, he found himself at the head of the roster for foreign service. The Barbados station just then fell vacant, and he was accordingly appointed to the post of Resident Engineer, and sailed from England in 1875 November. In 1876 March, he was appointed to serve as Aide-de-Camp to the Governor of the Windward Islands, Mr. Pope Hennessy, and he remained in this post through the riots of 1876, and up till Mr. Hennessy's departure from the Colony.

At the close of 1877 he was appointed Executive Engineer at Hong Kong, and he left Barbados in 1878 January, and, after a stay of about three weeks in England *en route*, reached Hong Kong in April, shortly afterwards receiving the additional

appointments of Engineer of the Admiralty Works at that station and Aide-de-Camp to the Governor.

In 1881 he drew up a design for a Physical Observatory for Hong Kong, to comprehend Astronomical, Magnetical, Meteorological and Tidal observations. This project and the report accompanying it * were referred to the Kew Committee of the Royal Society, who recommended their adoption without the alteration of a single item; and Major Palmer received the official thanks of the Secretary of State for the Colonies. Though the scheme was afterwards somewhat cut down by the Colonial Office, on the grounds of economy, the present Observatory, as far as it goes, is in conformity with his project—on which competent authorities have since pronounced in terms of the highest approval, insisting that it deserves to rank as a standard guide for constructing observatories of that class in the Colonies or elsewhere.

In 1882 Colonel Palmer was invited to conduct a second time an expedition for observing the transit of *Venus* (1882 December 6), at New Zealand, but declined the offer, having other aims in view. In the same year he made an exact determination of the latitude of the proposed Hong Kong Observatory Station (on Mount Elgin, Kaûlung), with observatory instruments lent for the purpose from the U.S. surveying-vessel *Palos*.

From 1883 onwards, Colonel Palmer did much engineering work in Yokohama. He designed and carried out extensive water works and harbour works; and his services to the Japanese Government were recognised by the third-class decoration of the Order of the Rising Sun from the Emperor of Japan in 1887. His graphic and interesting letters from "Our own Correspondent in Japan," which appeared in the columns of the *Times*, gave much valuable information about that country. In 1887 he retired from the Corps of Royal Engineers with the honorary rank of Major-General.

He had married in 1863 the eldest daughter of the Ven. Archdeacon Wright.

He was elected a Fellow on 1874 January 9, and in 1876 contributed to the Society a paper concerning the methods of the U.S. Coast Survey (*Monthly Notices*, vol. xxxvi. p. 300).

He died at Tokio on 1893 March 10.

CHARLES PRITCHARD was born at Alberbury, Shropshire, on 1808 February 29, being the fourth son of Mr. William Pritchard. After a few years at a private school at Uxbridge, he was admitted to Merchant Taylors' School in 1819 January, his attendance as a day-boy involving a long walk of four miles, in all weathers, before commencing work at 7 A.M.—a severe experience for a boy of 11. After a year and a half, he was removed to a school at Poplar, where the foundation of his

* See *Hong Kong Blue-books*, 1881.

scientific, and especially of his astronomical, training was laid; for a number of instruments and models made and used by the astronomer Ferguson, including some antiquated telescopes and quadrants, were put into the hands of the senior pupils for their instruction. He has himself recorded the fact that "very many of us could use the theodolite, and could survey and plot an estate. Our practice-ground was mainly in the Isle of Dogs, at that time an all but unoccupied waste; and I well remember how, at the age of less than sixteen, I earned two guineas for indoctrinating an intending colonist in the art of field-surveying."

His last school was Christ's Hospital, and he used to recall with satisfaction that for a twelvemonth he was placed at the head of the Deputy Grecians. Pecuniary difficulties at home compelled him, however, to leave, and he began to read for entrance to the University under particularly unfavourable circumstances; but by dogged perseverance on his own part, and with the assistance of friends and relatives, he entered St. John's College, Cambridge, in 1826. Here he worked well and successfully under Charles Jeffreys, who was Second Wrangler in Airy's year, 1823; and in 1830 graduated as Fourth Wrangler. He spent a couple of years in reading for his Fellowship, for which a knowledge of classics was then necessary, taking pupils at the same time, and was elected Fellow in 1832 March. He remained at the University a short time as a tutor, but being offered the headmastership of a school at Stockwell, formed under the auspices of King's College, London, he decided to leave Cambridge for the busier life near London. The school flourished under his guidance; but unfortunate differences with the governing body, which became more troublesome as time went on, caused him to resign the appointment, and he thought of returning to the University. But his talents had so far been appreciated by the parents of his scholars that they proposed to establish a new school over which he might preside with a freer hand; and the famous Clapham Grammar School was therefore founded in 1834. For nearly thirty years he here laboured successfully. His practical views of a liberal education have been well and fully described by one of his old pupils, Dr. Bradley, Dean of Westminster, in the *Nineteenth Century* for 1884 March. Five-and-twenty years after he had left the school, his old pupils gave a dinner in his honour, at which the roll was called over in the old style; and men bearing names honoured by the world—such as those of Airy, Darwin, Herschel, Hemming, Mivart, Pritchard—stood up in their places to let their old schoolfellows see and know them again in the flesh, and answered "Here, sir!" as in their schooldays. An outcome of the meeting was the publication of a short autobiography by Professor Pritchard.

His life at Clapham was brought rather suddenly to a close in 1862, when he transferred all his interests in the school, including a small observatory which he had built there, to Dr.

Alfred Wrigley, and retired to Freshwater, Isle of Wight. He was very anxious for pastoral work, but was disappointed in his endeavours to obtain it—a reverse which he felt very keenly. In the pulpit he was very successful, especially on occasions which gave him an opportunity of using his scientific knowledge in the interests of religion. He was invited to preach before the British Association at Nottingham in 1866, and this particular sermon had at least three important results: he was in 1867 appointed Hulsean Lecturer at Cambridge; his line of argument suggested to Vice-Chancellor Sir W. Page Wood a treatise on the "Continuity of the Holy Scriptures;" and the preacher was again and again invited to address the Association at its meetings—as in 1867 at Dundee, in 1868 at Norwich, and so on; so that he came to be called the "Chaplain to the British Association."

We now approach Professor Pritchard's definitely astronomical career. Apart from this, he was already a man of undoubted eminence in the educational world. But space cannot be spared in this Notice for more than the above brief notes of his scholastic and clerical life. He had been elected a Fellow of this Society in 1849, and contributed three small but interesting papers while still at Clapham—the first being on the "Amalgamation of the Mercury Trough;" the second (published in the *Memoirs*) a correction to Ideler's "Calculations of the Three Conjunctions of *Jupiter* and *Saturn* in B.C. 7" (which were conjectured to explain the phenomenon known as the Star of Bethlehem); and the third on "Some Photometric Experiments during the Annular Solar Eclipse of 1858." He also went with the Himalayan Expedition to Spain to observe the total solar eclipse of 1860. He was elected on the Council of the Society in 1856, Secretary in 1862, and President in 1866. During his seven or eight years' stay at Freshwater, he was thus taking a particularly active share in the affairs of the Society, in spite of the long journey to London. He built a small private observatory at Freshwater; but his contributions to the publications of the Society do not include any observations made by him there, being chiefly of the nature of comments and criticisms upon current astronomical work. His presidential addresses were delivered on presenting the Medal to Mr. (now Dr.) Huggins and Dr. Miller for their researches in Astronomical Physics, and to M. Le Verrier for his Solar and Planetary Tables.

On the death of Professor Donkin in 1869 November, Mr. Pritchard was elected to succeed him as Savilian Professor of Astronomy in the University of Oxford; and from that time to his death his astronomical life was a model of untiring zeal and energy. When he was appointed, his only appliances for teaching astronomy practically were a few small instruments which his predecessor had purchased privately, mounted behind the University Museum. Professor Pritchard applied to Convocation for an observatory worthy of the University, and his request

was granted in 1873 by the vote of a sum of 2,500*l.* for the purchase of a 12½-inch refractor and a suitable building in the University Parks. This grant was supplemented almost immediately by the generosity of the late Dr. Warren de la Rue, who presented to the University his own instruments, which had been erected at Cranford, including a 13-inch reflector, mounted equatorially, and a 13-inch reflector, mounted as an altazimuth. The Grubb 12½-inch refractor and the equatorial reflector were mounted under two domes, and the altazimuth in the building connecting them, computing rooms, &c., occupying the lower portions of the towers for the domes. Some years later a library and a fine lecture-room were added. The domes are truncated in form, as a concession to architectural effect, for the observatory occupies a conspicuous position in the Parks.

It is interesting to note that Professor Pritchard originally described the observatory as the "New Savilian Observatory for Astronomical Physics at Oxford." * It was the outcome of a representation to the University of the importance of the Savilian Professor "being furnished with instrumental means adequate to the instruction of his class, and for the purposes of original research."

No work in Astronomical Physics done at the observatory has yet been published; but there can be no question as to the success of the Director in using his opportunities for original research. He was particularly happy in selecting problems suited to the capacity of an academic observatory; and in solving each of them in turn. Three of minor and two of major importance he lived to see completed to a definite stage; the three are, "Measures of Photographs of the Moon;" "Work on Double Stars;" "Measurements of the *Pleiades*;" and the two, "Wedge Photometry," and "Photographic Stellar Parallaxes." He lived also long enough to initiate the work which falls to the Oxford University Observatory as its share in the international undertaking for forming a photographic chart of the heavens.

His work on the "Measurement of Lunar Photographs" takes rank as one of the earliest proofs of the accuracy of such measures. Rutherfurd had found in 1872 how accurately stellar photographs could be measured; but his work remained for many years unpublished, and was little known; and as regards work on objects like the Sun and Moon, the measures of the photographs of the Transit of *Venus* in 1874 had proved quite unsatisfactory. In *Monthly Notices*, vol. xxxviii. p. 513, Captain (now Colonel) Tupman concludes that the discordances "support the decision of the American Commission that the photographic diameter of the Sun cannot be relied on when accuracy is required." The lunar image, no doubt, differs in many respects from the solar; but still the value of Professor Pritchard's

* *Monthly Notices*, vol. xxxiv. p. 49. Other papers referring to the obser vatory and its development will be found in vol. xxxv. p. 376, and vol. xxxvi. p. 1 etc.

conclusion in his memoir "On the Moon's Photographic Diameter, and on the Applicability of Celestial Photography to Accurate Measurement" (*Mem. R.A.S.* vol. xlvii.), that "The result of all this protracted enquiry leaves no doubt on my own mind that measures taken on the photographic film are interchangeable with direct telescopic measures between the same points on the focal image of the Moon itself, but with this advantage in favour of photography, that the measures on the film can be examined or re-examined at any time, and at all times made in a leisurely manner"—the value of this conclusion consists in the fact that, familiar as it is to us now, it was then new, and must, therefore, be considered as a great advance in the history of the subject. It loses nothing in importance by the confirmation quoted in the same paper (p. 16, foot-note): "Since this paper was completed for publication, the elaborate discussion by the American astronomers of the results of the photographic measures of the Transit of *Mercury* in May 1878 have amply confirmed the conclusions regarding the reliability of photography, properly applied, as derived from the present investigations."

As regards the investigation of the lunar libration, to which the above research on the lunar diameter was incidental, the results of two series of measures are given in the same paper, and agree generally with those of Wichmann and Hartwig; but a new method of measurement had in the meantime suggested itself, whereby some of the systematic errors of that originally adopted might be avoided; but the results of the remeasurement have not yet been published.

Four volumes have been published, with the general title *Astronomical Observations made at the University Observatory, Oxford.*

The first may be regarded as preliminary, and contains observations of *Saturn's* satellites, of double stars, of comets of the year 1877, and the elements of the orbits of three double stars (*ξ Ursæ Majoris*, 70 *Ophiuchi*, and μ^2 *Bootis*), on which special attention was bestowed.

The second volume is the "Uranometria Nova Oxoniensis," and contains wedge photometer determinations of the magnitudes of all naked-eye stars from N.P.D. 0° to 100°—the record of three years' labour. In 1886 the gold medal of the Royal Astronomical Society was awarded jointly to Professor E. C. Pickering and Professor Charles Pritchard, for their photometric researches; and an excellent account of the work will be found in the President's address (*Monthly Notices*, vol. xlvi. p. 272). It may be mentioned that, in order to more thoroughly investigate the absorption of light by the atmosphere, Professor Pritchard, with his assistant, Mr. Jenkins, spent five or six weeks at the Khedive's observatory, near Cairo, in the early months of 1883.

The third and fourth volumes of the Oxford observations are

entitled "Researches in the Stellar Parallax by the aid of Photography." The third contains elaborate investigations of the parallaxes of the double stars 61 *Cygni*, μ *Cassiopeiæ*, and *Polaris*, and complete, though less extended, series of observations on α, β, and γ *Cassiopeiæ* and α *Cephei*. Professor Pritchard was led to restrict the number of observations made on any individual star in order that more stars might be examined, his aim being to obtain within a short time a general estimate of the parallax of all stars to the second magnitude; and this object he attained, the fourth volume of the Oxford observations giving the results for the remaining twenty-one stars. The idea of mapping out a research on such lines that it could be completed in a few years is characteristic of Professor Pritchard; and though it may have originated in his own case from the knowledge that the remaining years of his astronomical life, already a long and active one, could not be many, it is also particularly appropriate to the requirements of a university observatory. Professor Pritchard was careful to emphasise the completeness of the research by adding a historical survey of previous work on the same lines, both in the case of the photometric and of the parallax work; and these two essays are in every way worthy of their author. For his stellar parallax work he received the medal of the Royal Society, in 1892.

Two smaller but valuable investigations carried out by Professor Pritchard are well worthy of mention: the first, undertaken at the request of a committee of the Royal Society, being a "Report on the Capacities in respect of Light and Photographic Action of two Silver on Glass Mirrors of Different Focal Lengths" (*Proc. R. S.*, vol. xliv. p. 168), the verdict being in favour of the longer focus; and the second, his work in determining the magnitudes of selected stars, for the settlement of questions relating to the Astrographic Chart, and especially that of the value of the suggested gauze screens. Altogether the record of work accomplished would be well worthy of an energetic man in the prime of life, and excites our keenest admiration when we reflect that it is the record of a veteran astronomer from his sixty-third to his eighty-third year.

No notice of Professor Pritchard would be complete without a reference to his great love of flowers. It may be doubted whether the growth of the University observatory itself was more pleasing to him than that of the flowers and shrubs which he so lovingly nurtured round it, and of the creepers which he coaxed over its walls. Indeed, in the heart of the observatory, the stranger who opened a particular door was startled to find himself suddenly in a well-tended fernery.

Professor Pritchard took his M.A. degree at Cambridge in 1833, at Oxford in 1870, and D.D. at Oxford in 1880. He was ordained deacon in 1833, and priest in 1834. He was elected F.R.S. in 1840, and served on the Council in 1885–7. He became a Fellow of New College, Oxford, in 1883, as Savilian

Professor under the new statutes. He was made an Honorary Fellow of St. John's College, Cambridge, in 1886.

He was twice married: first in 1834 to Emily, daughter of J. Newton, Esq.; secondly in 1858 to Rosalind, daughter of Alexander Campbell, Esq., of Tunbridge Wells. His second wife died about a year before him. He died on Sunday, 1893 May 28, in the eighty-sixth year of his age. H. H. T.

Wesley Stoker Barker Woolhouse was born at North Shields on 1809 May 6. His father was a greengrocer in North Shields, and in the boy's earlier years he carried the wares to the customers. At an early age, however, he showed a great facility in solving mathematical problems, and was often stopped on his way with his basket by an old mathematician who delighted in testing his powers. He went to Leitch's school, a famous academy in North Shields, and doubtless owed much to the excellent teaching he there received. But his love of science was hereditary, for his father was a keen amateur astronomer, and, it is said, injured his sight by his devotion to observing; indeed, during his latter years he became quite blind, and his son would lead him by the arm for a walk in the fields. There is evidence extant of the interest taken in the clever boy by his teachers in the shape of three testimonials dated 1821 July, and signed by George Sharp, the head-master, and John Charlton and Robert Marshall "mathematicians;" the first of which commences: "This book contains 395 problems in Mensuration and Algebra, solved and written down in my school in thirty-six days, by Wesley Woolhouse, a boy aged twelve"—thirty-three of the problems being in quadratic equations—and concludes, "I have no hesitation in stating it as my opinion that, should he have the fortune to be taken under the patronage of the learned, his genius in mathematics will amply compensate their attention." He obtained the prize in the *Ladies' Diary* at thirteen years of age. Nothing of particular interest, however, is recorded about his next few years, until at nineteen he published a little work on "Geometry of Two Dimensions," and wrote a paper on "Analytical Dynamics," in both cases depending upon his own invention or rediscovery rather than on his reading of existing works, to which, apparently, he had not had access. About the same period many eminent mathematicians were contributors to the mathematical department of the *Newcastle Magazine*, and here Woolhouse gained several triumphs, as in the case of his own problem of a heavy bar falling over a pulley, to which he received only one solution. He thus became known as a mathematician throughout England, and when the *Nautical Almanac* Office was reconstructed in 1830, he was made deputy superintendent. The Almanac had previously been prepared under the Astronomer Royal's direction, and the contents had remained generally unchanged for many years. But a Committee appointed by the Royal Astronomical Society drew up an entirely new plan for the

work, which was adopted in the volume for 1834, under the superintendence of Lieutenant Stratford. The first edition of this volume, consisting of 7,000 copies, was published on 1833 July 19, and was entirely out of print on 1834 April 11, necessitating the preparation of a second edition. Mr. Woolhouse is mentioned in the volume as having had a large share in the final checking of the computations; but in the volume for 1835 he also wrote a valuable appendix, giving "Tables for Computing the Phenomena of Jupiter's Satellites;" and a smaller one on the "Computation of the Ephemeris of a Comet from its Elements." These were the first members of what proved to be a brilliant series, being followed by an admirably complete memoir on "Eclipses" in the volume for 1836 (occupying nearly 100 pages), and a fourth in the volume for 1837, on the "Determination of the Longitude from an Observed Solar Eclipse or Occultation" (which is preceded by Airy's paper on "Perturbations"). There is no doubt that he also wrote the memoir on "Halley's Comet" in the volume for 1839; but a difficulty arose between him and the superintendent, which led to his leaving the *Nautical Almanac* Office and becoming actuary to the International Loan Fund. It is not necessary here to enter into the merits of the dispute; but it is recorded of Woolhouse that such work as he did on Halley's Comet so exhausted him that he afterwards slept for thirty-six hours at a stretch.

About this period he gave in White's *Ephemeris* a new method of finding the latitude and longitude, which the late Mr. Edward Riddle characterised as one of the greatest improvements in nautical astronomy of the century.

His first important work relating to life assurance was in 1839, when he published his well-known "Investigation of the Mortality in the Indian Army;" and about 1844 he graduated the "17 offices" mortality table. But between that date and 1861, he does not appear to have written anything relating to a subject with which his name must ever be inseparably associated. But in 1861 he commenced a series of valuable papers in the *Journal of the Institute of Actuaries*, and for years scarcely a volume was issued without containing something from Mr. Woolhouse. Among the most important of these papers are those on "Interpolation, Summation, and the Adjustment of Mortality Tables;" on "The Construction of Mortality Tables;" and in an epoch-making paper in vol. xv. he gave an "Improved Theory of Annuities and Assurances," introducing in a consistent scheme the methods of the differential calculus into life contingency calculations. His last appearance at the Institute was in 1889, when he read a paper on an "Easy Method of getting out a Rough Estimate Valuation of a Whole-life Assurance Business."

A valuable piece of work, though not of an astronomical character, may perhaps be mentioned. When the discussions arising out of the Ten Hours' Bill were going on, the following question arose: How far the factory girls had to run in a day

when attending the "mules" and trotting backward and forward to tie the threads which were constantly breaking? The problem was one in probabilities, and Mr. Woolhouse's aid was asked by Lord Ashley. He went down to Manchester to obtain his data, and solved the problem, showing that the thread-tying girls ran upwards of thirty miles a day.

In 1858 a public dinner was given to Mr. Woolhouse by his fellow-townsmen of North Shields; and Mr. Dodd, the head-master of his old school, pronounced a eulogium upon him "as a man and a mathematician."

Mr. Woolhouse was an accomplished musician and editor of classical music. Only a few days before his death his name appeared in the *Times* as the arranger of a new issue of works by Hummel, and he was the author of a work on "Musical Intervals, containing an investigation of the temperament of the musical scale, and of the beats of imperfect concords." He also wrote a valuable work on the "Measures, Weights, and Coins of all Nations, and on the Measure of Time," and several mathematical text-books of great excellence.

Those who knew him unite in testifying to the charm of his character—simple and genial to a degree. Towards the close of his life he was very fond of needlework, which he reduced to an exact science, having formulæ for the constituent parts of the articles he made—even for the exact length of cotton to be used in each operation. His friends love to recall a verbal quip in which he used to delight—"What sum of money is the double of itself? One and tenpence, because it is two and twentypence." He lived to the age of 84½, and died in 1893 August.

He was elected a Fellow on 1836 May 13, but contributed no papers to the Society. H. H. T.

Dr. Rudolf Wolf, the Director of the Observatory at Zurich, died on 1893 December 6, at the age of 77, after a few days' illness. Dr. Wolf was born 1816 July 7, at Fällanden, near Zurich, and first studied astronomy in the Zurich High Schools, and later at the Universities of Vienna and Berlin. He did not devote himself entirely to the pursuit of astronomy until 1847, when he was appointed Director of the Observatory at Berne. In this small observatory he began the researches on Sun-spot phenomena, with which his name will be most intimately associated in future years. These observations he continuously carried on until his death, and his most important conclusions may be briefly summarised. On 1852 July 31, he showed the intimate connection between the periods of Sun-spot activity and of Earth-magnetism. These results were published simultaneously with, but independently of, those of Professor Lamont, of the Munich Observatory, and of Sabine and Gautier. Lamont and Sabine found a period of about 10 or 10⅓ years. Professor Wolf showed that this period might be more accurately repre-

sented by 11·11 years, and suggested also a longer period of 55·5 years. He also pointed out that there were considerable deviations from the mean period of 11·11 years, and that the difference in time between two maxima was shortest when their intensities were most marked. He clearly showed the resemblance between Sun-spot curves and those of the variation of light of stars. He collected much evidence connecting the manifestations of auroræ and other luminous phenomena with solar disturbances. Professor Wolf remained at Berne until 1864, when he returned to Zurich as Professor of Astronomy in the Polytechnic, and Director of the Observatory. Dr. Wolf's other contributions to astronomy embrace both pure mathematics and astronomical literature. In 1852 he published the first edition of his *Mathematics, Physics, Geodesy, and Astronomy*, the sixth edition of which was brought out very shortly before his death. In 1858–1861 he wrote four volumes of the *Biographies of Swiss Men of Science*. Two volumes of the *Handbuch der Mathematik* appeared in the years succeeding 1869, followed in 1893 by his *Handbuch der Astronomie, ihrer Geschichte und Litteratur*; his *History of Recent Astronomy* was published in 1877. The *Astronomische Mittheilungen* have continued from 1856 to the present date, and contain descriptions of instruments and scientific relics in the Zurich Observatory, and histories of Swiss mathematicians, physicists and astronomers, as well as important astronomical communications.

Professor Wolf was elected a Foreign Associate of this Society 1864 November 11.

Fabian Jacob, Baron Wrede of Elima, was born 1802 October 9, and died 1893 May 22. The Barony dates from 1605, when an ancestor saved the life of the King of Sweden, at the expense of his own, at the Battle of Kirkholm. The late Baron showed almost in infancy a decided preference for mechanical and scientific pursuits, but his studies in this direction were interrupted for several years by a military education. After completing this successfully, however, he received a staff appointment at Stockholm, and was again free to study science, though at the expense of some banter from his military companions, to whom the spectacle of a "grown man *reading* in the middle of the day" was quite novel. He was fortunate enough to make the acquaintance of the chemist Berzelius, who delivered a course of lectures at Stockholm in 1820, and a firm friendship sprang up between the two which was only terminated by the death of Berzelius. He was fond of music and literature, and thoroughly enjoyed the opportunities he had in Stockholm of developing these tastes. He was a Fellow, and at one time President, of the Royal Musical Academy of Sweden, and he was privileged to hear read before publication many of the works of his cousin, Miss Bremer, the famous Swedish novelist. But he did not neglect his military career, and his scientific attain-

ments were devoted to the improvement of artillery with very great success. In fact, he revolutionised the service—finding it quite old-fashioned, and leaving it in a state of the highest efficiency. In 1859 he was made General of the Ordnance and Chief of the Artillery; in 1867 a lieutenant-general; and he left the army in 1875.

Of his purely scientific work a paper on the absorption of light, published in 1834, is perhaps the most noteworthy. He was elected to the Royal Swedish Academy of Sciences in 1835, and ultimately became president, delivering an address on his retirement from this office in 1847 on the present and future of nineteenth-century science, which attracted much attention. As President of the Academy, he was elected an Associate of this Society in 1845, but contributed no papers to the Society. His work was chiefly spectroscopic.

From 1870 to 1879 he represented Sweden at the International Metrical Congress at Paris. He was very active, as a member of the Upper House in the Swedish Diet, in procuring the reform of the weights and measures and the adoption of the metric system. He was a member of the Association Géodésique Internationale. In 1845 he was at the head of a commission for measuring a part of the meridian in Lapland.

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the directors of the several observatories, who are alone responsible for the same:—

Royal Observatory, Greenwich.

An exceptionally large number of observations have been made in all departments of the observatory, owing in great measure to the fine weather which prevailed through a great part of the year. The total number of transits observed in the year was 11,262, and of meridian zenith distances 10,334, these numbers being just double of the corresponding numbers for the average of the five years preceding. The total number of stars observed with the Transit Circle during the year was 2,797.

The mean error in R.A. of Hansen's Lunar Tables with Newcomb's Corrections, as deduced from 142 observations with the Transit Circle, is $+0^s.036$, agreeing well with the results of previous years since 1883, which are as follows:—1883, $+0^s.032$; 1884, $+0^s.021$; 1885, $+0^s.028$; 1886, $+0^s.029$; 1887, $+0^s.068$; 1888, $+0^s.079$; 1889, $+0^s.010$; 1890, $+0^s.020$; 1891, $+0^s.079$; 1892, $+0^s.069$; 1893, $+0^s.036$.

A large number of observations of horizontal flexure of the Transit Circle by means of the collimators were made in the first half of the year under Mr. Thackeray's direction, for the thorough determination of any possible variability in this quantity. The mean flexure was found to be very small, as in previous years (the mean of 184 observations is $+0''.15$); but the discussion of the results is not yet completed. The apparent correction to nadir observations deduced from reflection observations of stars is $-0''.34$. This quantity has been persistently negative in every month of the year, and is slightly larger than the corresponding quantity for 1892, which was $-0''.25$. In 1891 and 1890 the values were $+0''.07$ and $+0''.08$. This apparent change in the discordance may be accidental, but as (according to past experience) it throws some suspicion on the errors of the microscope micrometer screws, the screws were examined in 1893 January and February; but

their errors, though not quite insensible, were found to have very little influence on resulting circle readings, owing to the reversal of three of the screws.

Observations of the Moon with the altazimuth in the first and last quarters have been continued as before.

Considerable progress has been made with the construction of the new Universal Transit Circle or Altazimuth, by Messrs. Troughton & Simms, which will, it is hoped, be ready for erection in the course of a few months.

Five comets have been observed during 1893 with the Sheepshanks Equatorial, viz.: Comet (*f*) 1892 (Holmes) on eleven nights; (*g*) 1892 (Brooks) on eight nights; (*b*) 1893 (Rordame-Quénisset) on eleven nights; and (*c*) 1893 (Brooks) on fourteen nights. With the view of determining the personal equation of different observers in observing objects of a cometary character, the following nebulæ were compared with neighbouring stars with the Sheepshanks Equatorial in the same manner as comets:—$\frac{1}{2}$ I 262 on three nights, and the Crab nebula in Taurus on five nights.

The planets *Mars* and *Ceres* were observed with the Sheepshanks Equatorial on five nights about the time of their conjunction in 1893. Thirty-one occultations of stars by the Moon, and 64 phenomena of *Jupiter's* satellites have been observed with the equatorials by one or more observers.

With the 12¾-inch Merz Refractor, mounted on the Lassell equatorial as mentioned in the last report, Mr. Lewis has obtained 864 measures of distance and 726 of position-angle of 120 double stars, viz.:—15 stars of distance less than 0″·5; 21 between 0″·5 and 1″·0; 43 between 1″·0 and 2″·0; 14 between 2″·0 and 3″·0; and 27 stars over 3″·0. The number of nights on which measures were made was 52. He also observed with this instrument the Conjunction of *Saturn* and *γ Virginis* on April 10 and 12. (*Monthly Notices*, vol. liii. p. 6.)

The new 36-foot Dome, by Messrs. T. Cooke & Sons, was completed at the end of April, and is very satisfactory. The new 28-inch Refractor, by Sir Howard Grubb, was mounted on the Great Equatorial in the course of last summer, and the adjustment of the object-glass was completed by Sir Howard Grubb on October 1, when, under good atmospheric conditions, the definition was found to be very satisfactory with powers of 800 and 1,300. Since then the instrument has been tested on *Jupiter* and on double stars, some measures of which have been made, and the colour-correction of the object-glass has been determined on stars by a number of readings for focus at different parts of the spectrum with a McClean spectroscope. The adaptation of the new tube to the existing mounting has taken much time, and the work is not yet completed, the dew-cap and various fittings at the eye end having only been received from Sir Howard Grubb within the last few days. The mounting carries the new telescope well, and the water-clock drives it

very satisfactorily, the disks of stars on a photograph with an exposure of 16 minutes being perfectly circular; but in view of the greatly increased weight of the tube, new slow-motion screws of larger diameter and finer pitch are now being applied.

With the Astrographic Equatorial, 1,020 plates, with a total of 2,400 exposures, have been taken during the year on 199 nights, and of these 200 have been rejected, viz.:—39 badly fogged plates, and 33 partially fogged, 44 sky cloudy, 27 for matters relating to *réseau*, 22 wrong setting, 5 not rightly put in carrier, 6 for bad clock-driving, 7 injured or broken, 13 badly developed, and 12 for miscellaneous defects.

The following statement shows the progress made with the photographic mapping of the heavens in the year 1893:—

	No. of Photos taken.	Successful Plates.
Astrographic Chart (Exposure 40^m)	301	235
Plates for Catalogue (Exposures 6^m, 3^m and 20^s) ...	498	372
Number of fields photographed for the Chart ...	...	213
„ „ „ for the Catalogue	...	367
Total number of fields photographed since the commencement of the work for the Chart ...	...	270
„ „ „ for the Catalogue ...	...	490

It has been made a practice to take a trail on each night on a catalogue plate as a check on the orientation, and during the past year plates with trails have been thus secured on 110 nights.

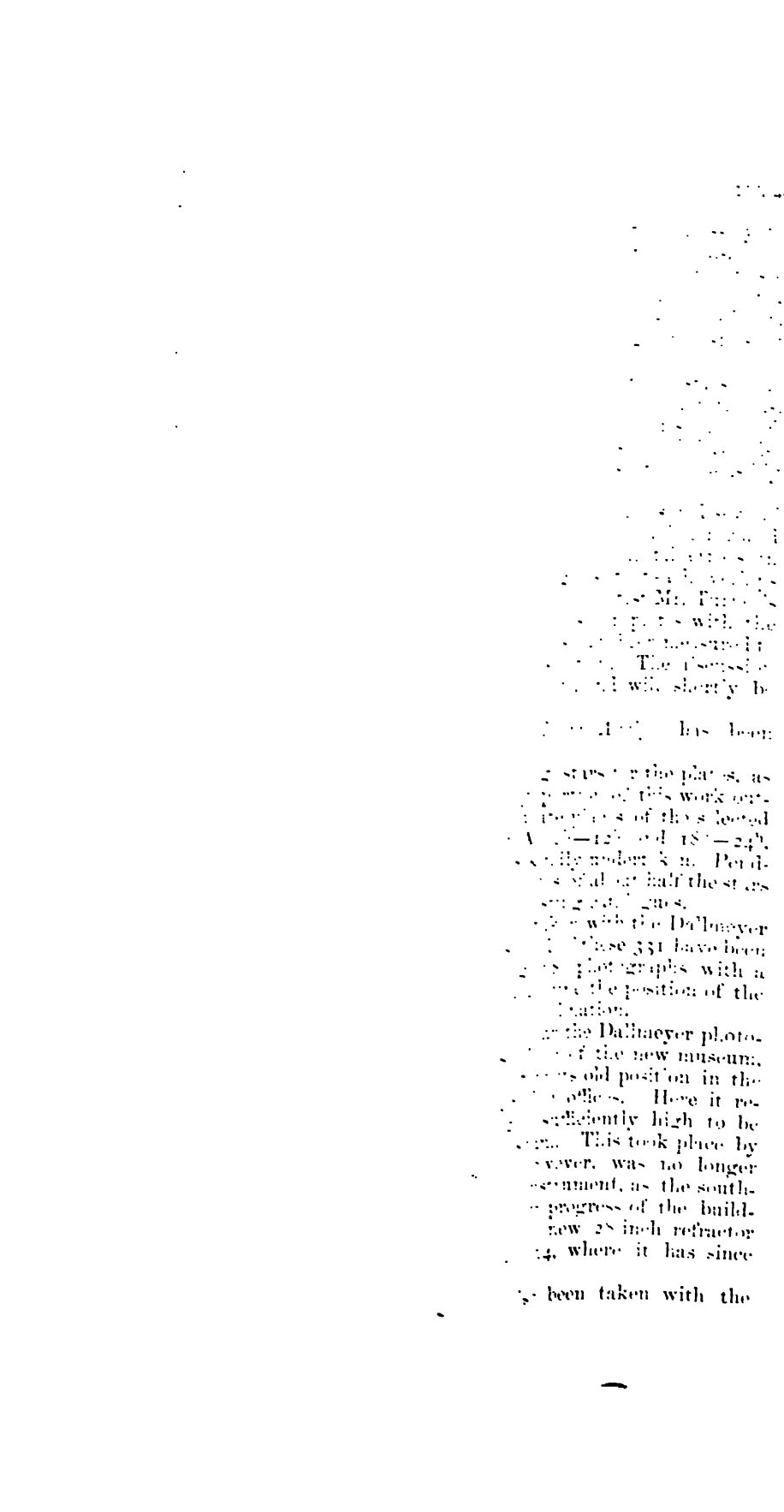
The following miscellaneous photographs (included in the total number of 1,020 given above) have also been taken:—

	No. of Photos.
Nova Aurigæ	33
For adjustments of Equatorial	33
Pleiades with various exposures	24
Plates of typical areas	52
Various regions	23

Nine of the *Pleiades* plates were taken with four exposures at the four corners of the plate for determination of the optical distortion of the telescope.

Some experimental plates of *Jupiter*, *Saturn*, double stars and lunar craters, have also been taken with the image enlarged about fourteen times by a secondary magnifier, consisting of a triple cemented concave lens of $1\frac{3}{8}$ in. diameter and 3 in. focus, supplied by Mr. T. R. Dallmeyer. The results are very promising.

The problem of protecting the *réseaux* from deterioration has



Thompson photoheliograph on 181 days during the year, and 283 of these have been selected for preservation. In all, photographs of the Sun have been taken at Greenwich, with one or both of the photoheliographs on 233 days during the year. Photographs have also been received from India and Mauritius up to 1893 November 22, leaving four days in the year ending on that day for which no photograph is yet available for measurement.

The increase in the solar activity, as evidenced by Sun-spots, has still continued through 1893, but at a diminished rate, and it is probable that the turning point has already been passed or is very near at hand. No single group has appeared equal in extent to that of 1892 February, but several have been observed quite equal to the largest groups of the previous maximum, and the numbers both of the individual spots and of complete groups have been very great, particularly during the months of August and December. The faculæ, however, which attained a most remarkable development in 1892, have shown a very distinct decline during the past year. A marked diminution in the latitude of spots is also noticeable. It is noteworthy that there has been a great decrease of terrestrial magnetic activity in 1893, the number of days of magnetic disturbance in 1893 being only about half of the corresponding number in 1892, which was remarkable for the extent and frequency of the disturbances.

The preliminary reduction of the observations for the longitudes of Montreal and intermediate stations has been completed and sent to Professor M'Leod for inspection before proceeding to the final reduction. The results are generally satisfactory.

The preliminary reduction of the observations for the longitude of Paris has been completed by both the French and the English observers; and a discordance similar to that shown in 1888 has again been found between the two independent determinations. Commandant Defforges came to Greenwich in June last to discuss the matter with the English observers, and it was decided to test the pairs of stations at each end for any spurious difference of longitude between the members of either pair. The results obtained at Greenwich to the present time seem on the whole unfavourable to the existence of an anomaly of this kind; but more observations are wanted before this point can be finally decided.

Mr. Plummer having arranged for a determination of the longitude of the Bidston Observatory, Liverpool, signals were exchanged on eight nights, Mr. Plummer making time determinations at Liverpool for comparison with the Transit Circle observations at Greenwich. He came to Greenwich from January 1–9 for determination of personal equation, but cloudy weather prevented observations.

The building of the south wing of the new Physical Observatory, commenced in 1892 November, is, after many delays, nearly complete. The building of the north wing and the

completion of the central octagon, on which the Lassell Equatorial and Dome are to be erected, have been sanctioned by the Admiralty.

In view of the introduction of a dynamo into the observatory-grounds for electric lighting, experiments were made in the early part of the year to determine the possible effect on the magnetographs of the dynamo unshielded and with triple iron shield. It was found that the effect of the unshielded dynamo would be sensible though small, but that the laminated shield rendered the disturbance insensible. The electric light installation, which has been ready for some time, is waiting the completion of the south wing of the Physical Observatory, in which the dynamo and gas-engine are to be placed.

The volume of Greenwich Observations for 1891 has been printed, and is in the binder's hands. The printing of the volume for 1892 is advancing.

Colonel von Sterneck, of Vienna, made some pendulum observations in the record-room of the observatory in April last.

Mr. T. C. Hudson resigned his position as assistant in July, and the vacancy has not yet been filled up. Mr. W. Ellis retired on December 31, after a long and honourable connection with the Royal Observatory of more than fifty years. Mr. W. C. Nash has been promoted to succeed him as Superintendent of the Magnetic and Meteorological Department, thus leaving another vacancy. Mr. Turner was on December 1 elected Savilian Professor of Astronomy at Oxford in succession to the late Professor Pritchard, and will shortly be leaving the observatory.

Royal Observatory, Edinburgh.

Favoured by the fine weather of the past year rapid progress has been made in the building of the new Royal Observatory. By the end of the year, the outer walls of the main building were finished, with the exception of the upper part of the larger or eastern tower and the balustrade round the flat part of the roof. The houses were completely roofed before the winter set in, thus permitting work to be carried on independently of the weather. Some progress has been made with the equatorial piers. A good part of the roads and paths have been laid out.

The erection of the granite piers of the Transit Circle and its collimators was begun on April 18, under the supervision of Professor Becker, who kindly gave his help in this important work. As there are no adjustments to the Ys of this instrument, great care is required to bring the bearings into position. The operation is, however, much facilitated by the use of a journeyman axis carrying a small telescope. The trunnions of

this axis are practically of the same dimensions as those of the Transit Circle itself, while the whole affair is so light that it can be reversed by hand. Eventually the massive cast-iron supports were adjusted bodily, both in height and in azimuth, within some 5″ of the truth. The blocks were then coated with vaseline and securely boxed in, pending the completion of the transit house. The framework of this house is now in course of erection, but some time must pass before the piers can again be tested.

The contract for the domes was taken by Sir H. Grubb in July, and every endeavour is being made to have them ready for putting up in the summer of this year. In July also the 15-inch refractor was dismounted at Dunecht, and in September the stand was slightly altered to suit the latitude of the new observatory.

The time-service at Calton Hill has been carried on as in former years, but the preparation of the weather returns for the Registrar-General for Scotland was on March 31 transferred to the Scottish Meteorological Society, by whose members the observations are made. On April 21, Mr. A. J. Ramsay was appointed temporary second assistant. In revising the earlier Edinburgh star-places, Mr. Heath has found it necessary to go back to the individual night's work. It is certain, however, that the increased accuracy of the final results thus obtained will amply repay the extra labour incurred. In this connection, a visit was paid to Professor Auwers in Berlin, who most generously gave us the benefit of his great experience in this class of work.

The 24-inch mirror was resilvered in May. All difficulty in accomplishing this with the face of the mirror upwards was overcome by following the suggestion of the Rev. Jevon J. Perry to surround the glass by a broad indiarubber band to contain the solutions. Four astronomical circulars were issued in the course of the year.

Royal Observatory, Cape of Good Hope.

Mr. George Maclear has, through severe illness, been unfit for duty since 1892 April, and the vacancy on the staff created by his retirement in 1893 June has not yet been filled. Two other members of the staff have been seriously ill during the year, and Mr. Cox has been away for six months in England, on well-earned leave of absence from duty. Thus the progress made in clearing off arrears of reduction and preparing results for press has not been so great as would otherwise have been the case. Undesirable as it is in the interests of science and for the healthy conduct of an observatory to suspend the continuity of its observations, it seemed to H.M. Astronomer necessary to continue the policy indicated in the last report—viz., to give up all meridian observing not absolutely required for immediate purposes, and to continue the efforts to overtake arrears of reduction.

With the Transit Circle accordingly there have been made only

Observations of R.A.	1003
„ N.P.D.	235
Determinations of Collimation	42
„ Level	90
„ Run	40
„ Nadir	41
„ Flexure	13

These observations have been limited chiefly to clock-stars, comet comparison stars, and special stars in *Centaurus* to assist Dr. T. J. J. See in his discussion of the relative masses of α^1 and α^2 *Centauri*.

The following occultations of stars by the Moon were observed:—

Disappearances at Bright Limb	2
„ Dark „	13
Reappearances at „ „	9
No. of separate phenomena	24

Some of these phenomena were observed by several observers.

With the zenith telescope 646 observations have been made by Mr. Finlay for Aberration and Change of Latitude.

With the 7-inch equatorial the following comets have been observed:—

Comet 1892 VI. on 22 nights
1893 II. „ 14 „
„ III. „ 15 „

With the photographic telescope 1382 plates were exposed.

	Plates.	Exposures. No.	Duration.
Catalogue plates	1164	3	(6^m, 3^m, 20^s)
Chart plates	99	1	(60^m)
Standard areas	102	3	(6^m, 3^m, 20^s)
α Centauri for measurement as a double star ...	1	20	
For study of photographic and visual magnitudes in different galactic latitudes	2	2	(5^m)
	13	2	(20^m)
An area in Cordoba D.M.	1	3	(6^m, 3^m, 20^s)
	1382		

Six of the plates exposed on standard areas were exposed also for 6^m, 3^m and 20^s on the South Pole area.

Of the 1,232 catalogue plates about 230 have been set aside as not coming up to the required standard. This rather large proportion of rejected plates seems to be due to the extreme diffusion of images which sometimes occurs in the heavy south-east winds which were prevalent during the year.

At the Cape the programme of the International Astrophotographic Congress has thus been realised to the following extent. Of 1,632 areas allotted to the Cape Observatory, 1,241 of the catalogue plates are finished and proved by comparison with standard areas to contain the stars of the required photographic magnitude, and to be sufficiently exact in position and orientation. Of the chart plates only 99 have been taken, with an exposure of one hour each; this series will now be more rapidly proceeded with.

The plate compared with the Cordoba *Durchmusterung* (central star C. D. M. $-29°$, No. 1216) shows marked discrepancies between the photographic and visual magnitudes. With 20^s exposure the star $-28°{\cdot}1081$ (magnitude 9·6) gives a measurable image, while several stars of 9·1 magnitude show no trace of an image with that exposure. Star $-29°{\cdot}1243$ (9·7 magnitude), on the other hand, is only just visible with 3^m exposure, and only just measurable with 6^m. Most images of the 10th magnitude stars give good measurable discs with 3^m exposure, but no trace can be found of the following stars, which are marked 10th magnitude, even with 6^m exposure—viz., $-28°{\cdot}1109$, and $-29°{\cdot}1185$. There is an image only just visible with 6^m exposure of $-29°{\cdot}1247$ (10th magnitude), yet on the same evening the standard stars, 1 to 12, on the Kapteyn-Pritchard area No. 2 (magnitudes 10·7 to 11·2), are all shown with 3^m exposure, although the standard area was photographed at a lower altitude and within a few minutes of the time at which the Cordoba area plate was taken.

The state of the reduction of the meridian observations is as follows:—

The Cape *General Catalogue* for 1885 (except the introduction) has been passed through the press.

The Introductory Tables, Ledgers, and Annual Catalogues for 1885, 1886, and 1887 are in course of printing.

The manuscripts of Tables, Ledgers, and Annual Catalogues for 1888, 1889, and 1890 are ready for press.

1891.—First copy of Ledger made.

1892.—Computation of mean R.A. complete to May 31. Computation of mean N.P.D. complete to December 31.

The observations of comets are completely reduced with approximate places of the comparison stars; the comparison stars have all been observed with the Transit-Circle, but the latter observations are not yet reduced.

A great amount of labour has been bestowed, since the date of last report, upon a complete rediscussion of the observations of *Victoria* made in 1889. The important change in the value

of the lunar equation, indicated by the first discussion of the observations, pointed to the necessity for a thorough examination of the whole question, and especially the consideration of all points bearing on the adequacy of the original ephemeris for the purpose of determining the value of the lunar equation, and deducing from it the mass of the Moon.

First of all, it was desirable to recompute rigorously the perturbations of the Earth by the Moon, not by the apparently approximate method of Le Verrier, but by employing approximate adopted values of the Moon's mass, and the solar parallax, and the true co-ordinates of the Moon. Secondly, it seemed very doubtful whether Le Verrier's Tables of the Sun (originally designed for computing apparent places accurate to $\pm$ 0″·1) could be relied upon to compute an ephemeris of the Earth, apart from the lunar perturbation, with sufficient arithmetical accuracy for our purpose. Thirdly, an examination showed that for the computation of the heliocentric co-ordinates of a planet from the elements, and the subsequent transformation to a geocentric ephemeris, seven figure logarithms were incapable of giving results of the requisite accuracy.

Dr. Tietjen kindly undertook the computation of a new ephemeris. Under his direction special perturbations and osculating elements were computed for P (the centre of gravity of the Earth and Moon). From these elements the Sun's co-ordinates (referred to P) and the heliocentric co-ordinates of *Victoria* were derived. Finally, from these co-ordinates an ephemeris of *Victoria* (referred to P) was computed. Eight figure logarithms were used throughout. The lunar perturbation of the Earth was then rigorously computed for every day, and applied, by differential formulæ, to reduce the ephemeris of *Victoria* to geocentric places. A comparison of the new and old ephemerides showed discordances amounting in several instances to more than 0″·1, partly due to the use of Le Verrier's Tables, partly to the use of only 7 figure logarithms in the computations.

The places of the planet were then independently interpolated from the new ephemeris for the epoch of each observation, and examined by differences from the previous values. New equations of condition were formed and controlled by those previously deduced. A new system of more approximate weights was then formed, and an entirely new discussion undertaken. The resulting value of the lunar equation is but little changed from the previous solution, but the residuals are barely one-half as great as those of the former one. It is now certain that Le Verrier's value of the lunar equation must be reduced by about 0″·1—viz., to about 6″·40. The definitive discussion is not yet quite completed. The observations have responded in a remarkable way to every refinement of reduction.

The reduction of the *Sappho* observations for parallax is

completed. Both *Victoria* and *Sappho* give 8″·80 for the solar parallax, within a few units of the third decimal place.

It has still remained impossible, with the inadequate computing force of the observatory, to attempt the reduction of the heliometer observations for stellar parallax, the observations of the mutual distances and position-angles of *Jupiter's* satellites, the Zenith Telescope observations, the measures of *réseaux* and photographic plates, the reduction of the occultations observed since 1881, and a valuable series of meridian observations of the Sun, Moon, and fundamental stars, made under Sir Thomas Maclear's directorate in the years 1861 to 1870, which should certainly be reduced and published.

Professor Kapteyn reports that the first volume of the Southern Photographic *Durchmusterung*, containing about 135,000 stars, is ready for press. The work will be completed in 3 volumes.

The computations of the Geodetic Survey were completed by Colonel Morris, R.E., before his departure from the Colony in September last. The work is in preparation for press.

The Observatory, Armagh.

A paper has been sent for publication to the Royal Irish Academy, containing the results of measures of one hundred nebulæ with the filar micrometer. About half of these objects have also been observed by Schönfeld, from whose results the Armagh observations differ rather less in Right Ascension than those of most other observers have done; while separate comparisons with the two series of observations of Schönfeld confirm the well-known systematic difference between them.

The refractor is at present employed on a series of measures of double stars. Aylmer-Leclanché low-resistance cells have been adopted for the illumination of the circles and micrometer, and have been found very satisfactory.

Cambridge Observatory.

The Transit Circle was used on 182 nights, chiefly in re-observing stars concerning which any question or doubt had arisen in arranging the catalogue, and in completing the observations of a few which had been overlooked or were so faint that they could only be observed under the most favourable circumstances. Where proper motion or variability has been suspected or confirmed, the star has been carefully looked after. Holmes's Comet was observed on the meridian on January 20, and the places of all the stars compared at this observatory with that comet were obtained as soon as possible from meridian

... r stars, beyond the limits
... special request from other
... number of clock-stars and
... ant, make up 1,725 meridian
... and level and collimation errors
...

... pleted to the end of the year.
... stars are entered in the larger
... of the last three hours of Right
... ged for entering.
... scension are entered in the smaller
... nearly ready for entering.
... e intervals of wires in the Transit
... observations of *Polaris* made in
... March.
... other observatories for places of
... d to. All the places, with hardly an
... catalogue.
... k, chiefly experimental, was attempted
... Equatorial, and was fairly successful.
... requently used in examining suspected

... *scope, Cambridge Observatory.*

... scope has been used for observation on 169
... the year 1893.
... k for driving the telescope arrived on
... was set up in position by January 23.
... its performance, and it was found that the
... clockwork was very satisfactory, but the
... in the driving worm made it necessary to
... again for correction, and the clockwork
... not available for another month- -March 20

... ington objective prisms have been used on
... photographs of spectra have been obtained,
... which have been rejected as valueless—
... is so.
... part of the year the spectrum of *α Orionis* was
... ly and photographically, and this study is still

... summer months the spectrum of *β Lyræ* was
... times. On account of the absence of compari-
... terrestrial source, and other causes, the reduction
... graphs has been attended with considerable diffi-
... yet completed.
... gained in obtaining these photographs points to
... the use of a telescope of focal length as great as

29 feet in conjunction with an objective prism is not desirable in our climate. Except on very good nights, the finer definition in the photographs is apt to be destroyed, presumably by the movement of the image on the plate in consequence of atmospheric tremor. In order to obtain the desired (linear) dispersion, it appears preferable to use great effective angle of prism in conjunction with short focal length of object-glass rather than to have a small angle of prism in conjunction with considerable focal length.

Experimental trials of different prism arrangements for a slit-spectroscope for photographic purposes have been made during the autumn. The net result appears to be to the effect that the conveniences of a direct-vision prism of the compound form are outweighed by the absorption of light in the dense flint prism. A new combination of prisms, in which only light flint is used, is now being tried.

Dunsink Observatory.

During the past year the meridian circle and chronograph have been devoted to the working list of stars with large proper motion, referred to in previous reports. This work, commenced in 1885, has been to a great extent interrupted since the beginning of the year 1888 by other observations with the meridian circle and by the photographic work with the "Roberts" 15-inch equatorial.

Throughout the year Mr. Lyster has devoted himself entirely to the work with this instrument, and distinct progress has been made with the working list. Of these stars, 514 observations of R.A. and 507 of Declination have been made. The observations up to June have been fully reduced to mean place for the beginning of the year, and the reduction of the later observations is in a forward condition.

In this work the clock corrections and the equator point of the circle are both deduced from observations of the *Berliner Jahrbuch* standard stars. In general, however, observations of the nadir point are also made by reflexion from a trough of mercury.

In the early part of the year a redetermination of the equatorial intervals of the spider lines in the meridian circle was made from observations of a number of stars near the pole, and complete tables of reduction deduced from them.

There have been 122 determinations of the collimation error of the instrument made during the year; the level error has been measured 191 times; the nadir point (by reflexion) 88 times; and the error of run of the microscopes 43 times, each observation consisting of three pairs of settings of the four microscopes.

There have been, in addition, 157 transits of azimuth stars observed. Also, for the purpose of determining the error of the Dent sidereal clock, 545 observations have been made of the R.A. of the *Berliner Jahrbuch* standard stars, and, for the purpose of determining the equator-point of the circle, the zenith distances of 344 of these stars have been observed.

With the "Roberts" photographic equatorial sixty-five plates were taken, including two of *Nova Aurigæ*, two of *h* and *χ Persei*, in continuation of the preliminary survey of this cluster published in the *Transactions of the Royal Irish Academy*, vol. xxx. Part IV., six of the cluster M 44 (*Præsepe*) intended for a similar survey, nine of the conjunction of *Saturn* and *γ Virginis*, which took place in April, and a number of working-list stars in search for parallax.

It was found, however, that it was impossible, even by keeping up a continuous watch (which made these observations most laborious), to avoid irregularities in the motion of the telescope, which far more than masked any parallactic displacement in R.A.; and a great deal of time has been occupied in trying to remove these irregularities, but hitherto not altogether successfully.

With the Troughton and Simms microscope 1,019 measures of photographs have been effected during the year. This instrument has been modified by the addition of an eyepiece micrometer containing two screws at right angles to each other, and a *réseau* is impressed on each plate in the ordinary way.

The difficulty of obtaining circular images with the 15-inch photographic equatorial has led Professor Rambaut to pay a good deal of attention to the various causes which tend to deform the photographic image of a star, besides irregularities in the driving-clock of the telescope. The most important of these is a want of accurate adjustment in the position of the polar axis of the instrument, to which attention is drawn in a paper read before the Society at its December meeting. In this paper it is shown that for photographic work this adjustment must be made with much greater nicety than is necessary for visual observations.

Another cause of deformation of the stars' images, which operates at low altitudes, is described in a paper "On the Distortion of Photographic Star Images due to Refraction," published in the *Proceedings of the Royal Dublin Society*, vol. viii. (N. S.), Part II., No. 18.

On December 9 the Board of Trinity College directed that a new 18-foot dome should be constructed for this telescope, in place of the old and almost immovable one under which it has been hitherto housed. This dome, which will have a wide sector opening, with a shutter on Dr. Gill's principle, and be provided with Sir Howard Grubb's best new system of live rollers, is at present in process of construction by Sir Howard Grubb, and will, it is hoped, be erected early in the spring.

During the summer and autumn months a number of measures were made with the new Grubb micrometer attached to the "South" refractor, for the purpose of determining the irregularities and the scale values of the screws. These consisted of 354 micrometer measures of distance and 450 transits of stars. The result of these observations shows that, except for a small part at the end of the range of one of the two screws, their irregularities are contained within very narrow limits. The "South" refractor has also been occasionally used for the measurement of double stars, and for determining the scale value of the photographs; and on the first Saturday of each month it has been put at the disposal of visitors to the observatory.

Glasgow Observatory.

Pending the reorganisation of the observatory, the Transit Circle has been employed only for time observations. Funds will shortly be forthcoming for effecting the much needed alterations to the Transit Circle, and for procuring some accessories for the 20-inch reflector and the 9-inch refractor; these two instruments have been taken down and are now in working order. The meteorological observations have been continued as in former years.

Liverpool Observatory.

The routine work of the Liverpool Observatory has been prosecuted throughout 1893 without interruption. This routine work comprises the determination of time and distribution to the Port of Liverpool, the rating of chronometers deposited by makers and shipowners, and the maintenance of the series of meteorological observations. In the first of these departments it is found that the mean error of time throughout the year, signalled by the flash of the gun, has been $0^{s}\cdot2$, irrespective of sign. In the chronometrical department 417 chronometers have passed through the observatory during the year, in addition to the 62 which were in charge of the department on 1893 January 1. This is a somewhat larger number than in previous years. In connection with this subject it may be mentioned that the Mersey Docks and Harbour Board have within the last few months completed arrangements for the testing, not only of chronometers other than marine, but of various scientific apparatus, which, it is believed, will make the observatory of greater use to opticians and the trade of Liverpool. Details connected with this new development have necessarily occupied much of the Director's time and attention.

Owing to a diminished staff, very little progress has been

made in the reduction of the accumulated mass of meteorological observations mentioned in the last report to the Council.

An inquiry into the value of the longitude used showed that the quantity employed might be considerably in error. At the time of the removal of the observatory from Liverpool to its present site, very insufficient means appeared to have been taken to secure the necessary accuracy, and the original determination of the longitude of the old observatory rested on the results of the chronometrical expedition, undertaken for the inquiry into the longitude of Valentia in 1842, under the late Sir G. B. Airy. Under these circumstances, application was made to the Astronomer Royal to arrange for a new determination by means of galvanic signals. This application being favourably entertained, an exchange of signals was effected last August. But inasmuch as recent experiments have proved that, however consistent with each other observations of one series may be, a repetition of the inquiry is apt to disclose noticeable discrepancies, it was made a part of the original scheme that after an interval of some months the signals should be repeated. This second series has not yet been effected.

Meanwhile a determination of the latitude has been proceeding by the method of transits over the Prime Vertical. This series of observations will be brought to an end about the time of the completion of the second interchange of signals, when papers will be presented to the Society on the subject.

The attempt to determine the parallaxes of some of the binary systems by the method of chronographic registration of transits, instituted with so much success by Dr. Kapteyn, has been interrupted, owing to irregularities in the performance of the chronograph; but this instrument being now in perfect order, the attempt will be renewed. The equatorial has been employed in the observations of comets, the results of which have been published in the *Monthly Notices*.

In the autumn a course of lectures on the Theory of Instruments was given in the observatory, under the auspices of University College, Liverpool, to students connected with that institution.

Radcliffe Observatory, Oxford.

The staff has been engaged during the year in securing the observations necessary for the completion of the *Radcliffe Catalogue of Stars*, 1890, and in its preparation for the press. The printing of the Catalogue has commenced and will be pushed on as rapidly as possible.

The observations of the Moon on the meridian have been continued as usual; the lunar results for 1892 have been reduced and discussed, and have been published in the *Monthly Notices*.

Observations of *Nova Aurigæ* have been frequently made to detect changes in magnitude, but no sensible changes were noted during 1893; and observations of Holmes' and Rordame-Quénisset's Comets have been secured.

The meteorological work has been carried on as usual.

University Observatory, Oxford.

During the past year the observatory has suffered the severe loss of its eminent Director, the Rev. Charles Pritchard, D.D., F.R.S., who died on 1893 May 28. Mr. H. H. Turner, Chief Assistant at the Royal Observatory, Greenwich, was appointed to succeed him in the Savilian Chair of Astronomy and Directorship of the Observatory on 1893 December 1. Mr. Stone, the Radcliffe Observer, kindly superintended the work of the University Observatory from June to December.

The Astrographic Telescope has been in use throughout the year, and 190 plates have been taken with exposures of 6 minutes, 3 minutes and 20 seconds ("Catalogue" plates); as well as 19 plates of the *Pleiades*, and miscellaneous plates.

As mentioned in the last report, the late Director initiated a research on the relative parallaxes of the stars in the *Pleiades*, and 70 plates in all have been taken of this group, the earliest date being 1892 August 11 (altitude 25°), and the latest 1893 March 4 (altitude 45°). Two of these plates have been completely measured, and three others partly measured. The reductions of these are well advanced, and it is intended to make every effort to satisfactorily complete this research, which will in many respects be a valuable preliminary to the measurement of the plates taken definitely for the Photographic Chart.

The Barclay Transit Circle was thoroughly readjusted last May and illuminated with electric light. It has since been in regular use for determining time.

The staff of the observatory, in addition to the Director, consists at present of three persons: Mr. F. A. Bellamy, appointed Assistant on 1892 September 1; Mr. F. W. A. Bennett, appointed Junior Assistant on 1893 April 6; and Mr. Mullis, a capable workman who has been of great service to the observatory in miscellaneous ways since 1876 January 1.

Temple Observatory, Rugby.

The measurement of the position and distance of double stars has occupied the greater portion of the time available after scholastic work has ceased, but, owing to the considerable number of members of the school attending last year, the original work is not large.

A few photographs of the spectra of some of the larger stars have been taken, with a view to measure motion in the line of sight.

Stonyhurst College Observatory.

The event of the year at this observatory has been the erection of the Father Perry Memorial, which, as is known, consists of a 15-inch objective adapted to the existing equatorial. The old telescope was built in three lengths: a strong cast-iron central box bolted to a flange at the extremity of the Declination axle, and two tubes, one for the objective, and the other for the eyepieces. These tubes have been replaced by two longer tubes, one of 16 inches diameter for the object-glass, the other of $8\frac{1}{2}$ inches diameter for the eyepieces. There are two finders attached to the eye-tube, and these have been raised by extension-brackets, to give them clear sight-lines over the wider tube. These adaptations, together with the objective, are the work of Sir H. Grubb; and the general appearance of the transformed equatorial is the best encomium upon his design for the enlarged telescope.

The measures of the Solar Chromosphere and Prominences have been suspended during the year, owing to the necessary interruption of the series by dismounting the telescope for the preparation of the new fittings. But the Sun-spot drawings have been continued with a 6-inch objective mounted on the equatorial stand during the absence of the principal parts of its telescope.

In the first months of the year the series of spectro-photographs of the brighter stars was continued; but in May this was interrupted in order to secure as complete a record as possible of the changing spectrum of *β Lyræ*. A careful examination of these plates has been made, and the results have been communicated to the Society in a paper published in the last December number.

About 350 photographs of solar-spot spectra in the green-yellow region, and 180 of faculæ reversals of the H and K lines, on half the number of plates, have been obtained with the large grating spectrograph. Nearly all the exposures were made during the summer half of the year, the low winter Sun having proved too unfavourable for the work; it was hardly possible to keep the spot or facula sufficiently stationary during the longer time needed for a good picture. A preliminary examination of the spot-spectra has been made, and some of the best plates have been compared with an artificial spot-spectrum formed by the shadow of a thread across the slit during half the time of exposure. The result of this comparison, made by a friend who was unaware of the artifice, was that all the lines over the imitation-spot band were widened, while the widening over the

real spots was selective. The widening therefore, if real, is at best a differential between two small quantities—the photographic effect, and the spot absorption. It has therefore been decided to discontinue this work until the means have been found to give sufficient light for an enlarged image of the Sun upon the slit. The two reflectors of the heliostat are apparently very good flats, for the definition of the spot as seen by the third and direct reflection from the grating is very good; but they are too small to cover the 4-inch objective with the reflected solar light; and several attempts to photograph the spectra of enlarged spot-images have shown that the time of exposure is too long.

Dr. Common's Observatory, Ealing.

Very little observing work has been done during the past year. Some time was devoted to assisting the preparations for observing the total eclipse of the Sun in April last.

The 5-foot mirror referred to in last year's report has turned out better than was expected, as through some inadvertence it had a hole cast in it similarly to the first.

A number of experiments have been made with a view of getting a more convenient form of large reflecting telescope, with a promising amount of success. A number of plane mirrors have been made, as well as a number of experimental mirrors of various kinds.

An apparatus has been made and mounted for the purpose of testing plane mirrors on the method devised by Lord Rayleigh, and found to work most satisfactorily.

Bermerside Observatory, Halifax (Mr. Crossley's).

As in past years, the work of this observatory has been the measurement of binary stars, the observation of the phenomena of *Jupiter's* and *Saturn's* satellites, and the usual meteorological observations for the Registrar-General and Mr. Symons.

Wolsingham Observatory (Rev. T. E. Espin's).

The sweeping for stars with remarkable spectra has been continued as in former years. The number of stars found is 578, of which 489 are new. Three new variable stars have been discovered, and the confirmation of the variation of three others has been obtained by photography.

(1) Variable stars found at the Wolsingham Observatory during the year 1893 :—

	Place 1900. α	δ	Variation.	Type of Spectrum.	Method of Discovery.
	h m	° ′			
D.M. +56°724	2 43·3	56 34.	Var. 8·5–9·5?	III.	By photography
Anonymous	19 9·1	25 50.	Var. 9·0–12·0.	III.?	
Anonymous	20 48·5	46 57.	Var. 9·1–13·0.	III.?	

(2) Stars whose variation has been confirmed in 1893 :—

	Place 1900. α	δ	
	h m	° ′	
D.M. +36°3168	18 28·9	36 55.	Suspected by Birmingham ; confirmed by Safarik. Also by photography. Type IV.
D.M. +36·3243	18 39·4	36 52.	Suspected by Safarik ; confirmed by photography. Type IV.
D.M. +36·3852	20 0·8	36 32.	Suspected in 1888 ; confirmed by photography. Var. 8·0 to 9·2. Type III.

Dr. Huggins' Observatory, Upper Tulse Hill.

During the past year the weather has been very unfavourable for continuing the spectroscopic work on faint objects, which has been in hand for a considerable time ; nevertheless some progress has been made in several series of observations.

As much attention as possible has been given to *Nova Aurigæ*. In 1893 February a number of spectroscopic observations by eye were made upon it with the 15-inch achromatic. Since then spectro-photographic observations have been made with the 15-inch, and a careful study by eye has been made of the object with the 18-inch Cassegrain reflector.

A great deal of delicate labour has been spent this year in testing and adjusting two new spectroscopes designed by Dr. Huggins, which have been added to the equipment of the observatory by the Royal Society.

Rousdon Observatory, Lyme Regis (Mr. Peek's).

This establishment is maintained in efficient working order. The exterior of the building has been repainted, and the interior of the dome coloured a deep blue, which is found peculiarly restful to the eye, and greatly to assist in the observation of very faint objects, such as variable stars at about their minimum.

The year 1893 has been singularly favourable to astronomical work, and observations have been made on 191 nights, which is about 30 above the average. Observations of the "long-period

variable stars" have been continued, and 537 determinations of magnitudes obtained, this being the highest number during the eight years of these observations.

The *Andromeda* Nebula (31 M) and the place of the temporary star of A.D. 945 have been regularly observed, but in neither case has anything remarkable been noticed.

The usual observations of clock stars have been taken. The rate of the sidereal clock by Grubb, which was erected in 1888, has greatly improved, and Greenwich Mean Time is furnished to the district.

Instrument in use, 6·4-inch equatorial refractor. Powers 34, 80, and 132.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

During the year ending 1893 December 31, the photographic work at this observatory has been steadily pursued, with the result that a considerable number of photographs of the Sun, Moon, planets, star clusters and nebulæ have been obtained.

The following list of photographs, with long exposures of the plates, is given in continuation of a similar one published in the *Monthly Notices*, vol. liii. pp. 254–5.

	R.A.	Decl.	Expos.
	h m	° ′	m
Neb. M. 33 Trianguli	1 28	N. 30 7	... 4^h
Neb. M. 74 Piscium	1 31·5	„ 15 15	72 and 3^h 40^m
Neb. M. 76 Persei	1 35·5	„ 51 2	90
Cl. H VI. 31 and H. VII. 46 Cassiopeiæ	1 38·5	„ 60 43	60 (2 photos.)
Neb. H I. 156 Persei	2 33·5	„ 38 37	... 3^h
Neb. H I. 64 Ceti	2 41	S. 8 1	90
Comet "Holmes" January and February			
Nova Aurigæ, January			
Cl. H VI. 25 Persei	3 7·5	N. 46 51	90
Cl. H VII. 61 Persei	4 7	„ 50 58	60
Neb. H I. 122 Eridani	4 36	S. 3 3	90
Cl. M. 36 and Neb. H I. 261 Aurigæ	5 27	N. 34 6	90
Neb. H IV. 33 Orionis	5 31	S. 6 46	90
Neb. H V. 28 Orionis	5 36·5	„ 1 54	90
Cl. M. 37 Aurigæ	5 45	N. 32 31	90
Cl. M. 35 and H VI. 17 Geminorum	6 2	„ 24 21	66
Pleiades on February 12, 16, and 19, with exposures of plate during	...	...	... 5^h 24^m

	R.A. h m	Decl. ° ′	Expos. m
Cl. H VI. 27 Monocerotis	6 46	N. 0 35	60
Cl. M. 50 Monocerotis	6 58	S. 8 11	90
Neb. H II. 316–317 Geminorum	7 19	N. 29 42	... 3h
Cl. H VI. 1 Geminorum	7 32	„ 21 49	60
Cl. H VI. 22 Monocerotis	8 8·5	S. 5 29	60
Gt. Neb. Orion with two exposures of 60m each on March 11 and 17			
Neb. H I. 200 Leonis Minoris	8 46	N. 33 49	... 3h
Neb. H I. 205 Ursæ Majoris	9 45·5	„ 51 34	90 and 3h 30m
Neb. H I. 56 and 57 Leonis	9 26	„ 21 59	... 4h
Neb. H I. 168 Ursæ Majoris	10 12	„ 41 57	90 and 4h
Neb. H II. 44 and 45 Leonis	10 12	„ 22 21	... 2h
Neb. M. 95 Leonis	10 40	„ 12 18	... 3h
Neb. H I. 17 and 18 Leonis	10 42·5	„ 13 10	90
Neb. H I. 116 and 117 Leonis	10 44	„ 33 33	... 3h
Neb. H I. 13 Leonis	11 0	„ 0 32	... 3h
Neb. M. 97 Ursæ Majoris	11 7	„ 55 56	90
Neb. H I. 194 Ursæ Majoris	11 20	„ 44 10	90
Neb. H II. 103, &c., Leonis	11 35	„ 15 55	... 3h
Neb. H I. 193 Ursæ Majoris	11 47·5	„ 37 34	90
Neb. H V. 45 and H IV. 61 Ursæ Majoris	11 48	„ 52 55	... 2h
Neb. H I. 223 Ursæ Majoris	11 54	„ 51 33	72
Neb. H I. 195 Ursæ Majoris	12 1·5	„ 43 39	90
Neb. H I. 165 and H II. 642 Canum Venaticorum	12 5·5	„ 40 1	64
Neb. H I. 95 Canum Venaticorum	12 10	„ 36 54	90
Neb. H I. 35 Virginis	12 10·5	„ 13 44	90
Neb. M. 100 Virginis	12 17·5	„ 16 24	90
Neb. H I. 210 and H V. 43 Virginis	12 18	„ 47 35	90
Neb. M. 17 Clypei Sobieskii	18 14·5	S. 16 13	... 2h
Cl. M. 26 Clypei Sobieskii	18 39	„ 9 30	90
Gt. Neb. Andromedæ, three plates taken on August 10 and 2, with exposure of 90 minutes each			
Neb. H III. 743 Aquilæ	19 13	N. 6 20	90
Neb. Star H IV. 73 Cygni	19 42	„ 50 16	60
Neb. H V. 15 Cygni	20 44	„ 30 20	... 2h 17m
Cl. M. 72 Capricorni	20 48	S. 12 56	90
Neb. H I. 192 Cephei	20 57	N. 54 9	... 3h

Enlarged copies of some of the objects referred to in the above list have been presented to the Society, and also lantern slides shown at the meetings. It is hardly necessary to add that almost every one of the photographs which have been enumerated in the lists adds materially to our previous knowledge of the structure and form of the object.

In the report for last year a reference was made to an intention to publish some of the photographs of stars, star clusters, and nebulæ, so as to make them available for astronomical researches. This intention has so far been carried into effect that the whole of the printed matter is already complete and the printing of the photographs is in progress, though the dull weather is causing delay. The whole of the enlarged positives required to complete the work are in the hands of the printers.

Mr. W. E. Wilson's Observatory, Streete, Co. Westmeath.

During the past year the principal work was an investigation on the effective temperature of the Sun. The research was made with an instrument especially designed for the work—a differential radio-micrometer. The principle was *balancing* the solar radiation by the radiation from a strip of platinum which was heated by an electric current. The temperature of the platinum strip was determined experimentally with great accuracy. The temperature of the solar photosphere given by this method is 6800° C. This investigation was carried out with the valuable aid of Mr. P. L. Gray, B.Sc., and the results have been sent to the Royal Society.

Observations were also made on the thermal radiation from Sun-spots.

A photograph was taken in the autumn of the *Dumbbell* Nebula, with an exposure of two hours in the 24-inch reflector. O. Struve, in 1852, having carefully determined the positions of all the small stars in the nebula, it seemed of interest to compare the photograph with these and see if there is any evidence of proper motion in this nebula. The negative has been sent to Dunsink Observatory, where Dr. Rambaut has kindly offered to have the positions measured.

Adelaide Observatory.

In the last notice on the work of the Adelaide Observatory it was stated that the Transit Circle was being devoted to observing the stars in the Weisse-Bessel Catalogue between 0° and 15° South Declination, including any other stars within that zone down to the 9th and 10th magnitude. This has been

temporarily laid aside, and during the past year we have mainly devoted ourselves to the observation of a large number of zenith and circumpolar stars, the latter with a view to a correct determination of latitude, and the former on account of the discrepancies in the declination of these stars as given in the Melbourne, Cape of Good Hope, and the Argentine Catalogues. For this purpose careful observations have been made of 244 stars near the zenith, and 123 circumpolar stars.

Between 1892 July 24 and 1893 August 17, 795 observations were made of zenith stars, and 450 circumpolar, of which 235 were made above and 215 below the poles. Since August we have confined ourselves principally to careful determination of the zenith distances of stars situated between the horizons of Greenwich and Adelaide, selected from the Greenwich Ten Year Catalogue of 1880, with a view to comparing the resulting declinations with those given at Greenwich. By the end of the year, 634 observations in zenith distances were made, and the work is still being continued, the greatest care being taken to secure good results.

Special attention is paid to determination of nadir, which is taken always twice, and occasionally three times, during each evening's observing. This appears to be necessary, as our experience has shown that it is subject to appreciable fluctuation in the course of a few hours, probably due to changes of temperature.

		1891.	1892.	1893.
No. of observations in R.A.		3,204	783	649
,, ,,	Declination ...	2,342	3,142	1,380
,, ,,	Nadir	89	271	324
,, ,,	Levels	91	73	42
,, ,,	Azimuth ...	66	48	32
,, ,,	Collimation ...	93	57	18

The meridian work is mainly carried out by the senior assistant, Mr. W. E. Cooke, M.A., and the reductions are nearly completed up to date.

In conjunction with Commander Usborne Moore, R.N., in command of H.M. surveying vessel *Penguin*, telegraphic determinations have been made of the difference of longitude between Adelaide and Port Darwin, Broome (Roebuck Bay, Western Australia), Fremantle, and Albany, the results of which have been published by the Hydrographic Department.

The equatorial has been employed mostly in observations of the phenomena of *Jupiter's* satellites, and sketches of that planet, besides occultations, &c.

The examinations of candidates for surveyors' licences are conducted at the observatory, and every Friday evening the institution is open to visitors, by special appointment.

Meteorological observations have been carried on as usual.

There are nearly 400 rain gauges distributed over the Colony, from the south to the north coast, besides a number of fully equipped stations.

Daily weather forecasts are issued by the Government Astronomer (Sir Charles Todd), with the following results:—80 per cent. fully verified; 13 per cent. partially verified; 7 per cent. wrong.

The staff consists of—Government Astronomer: Sir Charles Todd, K.C.M.G., also Postmaster General and Superintendent of Telegraphs. First Assistant: W. E. Cooke, M.A.; Second Assistant: R. F. Griffiths; Third Assistant: E. P. Sells; and two computers.

Hong Kong Observatory.

During the past year the time-ball was dropped daily at 1 P.M. Some lunar transits and some shooting stars were observed, and absolute magnetic observations were made regularly.

Madras Observatory.

The work of this observatory has again been chiefly confined to the maintenance of the time service, and to the reduction and publication of the arrears of observations. The meridian-circle observations have been printed up to the end of 1881, and vol. vii., bringing the results up to the end of 1882, would have been published before the close of the year had it not been for the heavy work involved in the correction of the old reductions for the erroneous positions adopted for some of the stars used in determining the meridian error. The most important incident of the past year in connection with the observatory is the sanction given by the Secretary of State for India to the proposals made by the Government of India regarding the future of the observatory. The observatory, which has hitherto been under the Madras Government, will, from 1894 April 1, be transferred to the Imperial Government. A new observatory for solar physics will be erected at Kodarkanal, on the Palani Hills, under the direction of the present officiating Government Astronomer, who will, for the present, also have charge of the existing observatory. The new observatory will undertake the work of solar photography, now carried on at Dehra Dûn, and will also take up spectroscopic work on the Sun, and actinometric researches. The present financial pressure on the Government of India may delay the carrying out of this scheme, but it is hoped that the work of building may be at least begun during the current year.

Melbourne Observatory.

During the year 1893 the meridian work has been carried on as usual, and has included, besides the usual standard clock and other stars for instrumental errors and time, a list of stars for use in the astrographic operations. The places of 3,175 stars in R.A. and of 1,798 in N.P.D. were determined during the year.

The astrographic work progressed but slowly, owing to persistent and somewhat unusual cloudy nights, and only 308 catalogue plates were obtained during the year, making the total number 711 up to end of year. The want of durability in the *réseaux* with the silver film has been a great hindrance. They all get riddled with pinholes, even before they arrive in Melbourne, and stopping up with China ink goes on till many of the lines are obliterated. We have been compelled to make some *réseaux* ourselves, by coating glass plates with an asphalt varnish and ruling in the observatory micrometric machine. *Réseaux* of this kind have stood very well. Some have been made over a year and do not show a single pinhole. The only objection is, the lines cannot be ruled quite so fine as on silver, but they require an exposure of only a few seconds, instead of minutes, and the lines develop fine and clear.

The reductions in the staff which took place last year have rendered it impossible to undertake much new work, and but little extra-meridian observing has been done.

The magnetical and meteorological work has been carried on as usual, including the issue of a daily weather chart and forecast. Amongst the special work of the year may be mentioned an investigation of the tides of Port Phillip, some experiments for obtaining more accurate clock errors, and a series of pendulum observations, consisting of a complete set of swings by Mr. Baracchi (chief assistant), of the Royal Society's pendulums (Kater's Invariable) Nos. 4, 6, and 11. These pendulums were lent by the Royal Society to the observatory for the purpose of obtaining the value of "g," and thus connecting it with Kew and Greenwich, forming a base for a gravity survey of Australia which the Royal Society of Victoria proposes to have carried out under its auspices.

These pendulums arrived in November 1892, and were soon afterwards set up in a basement in the observatory. A considerable period was occupied in preparation and preliminary work, and in June the regular swings were commenced by Messrs. Baracchi and Love, a complete set of swings with each pendulum being obtained by both observers. All the swings were made at ordinary pressures and temperatures. The latter were remarkably constant throughout, and the whole series is considered satisfactory.

During the progress of this work, Lieutenant Elblein, an officer of the Austrian warship *Saida*, obtained a series of swings with a set of Colonel von Sterneck's half-second pendulums, which will eventually connect this observatory with the Vienna gravity base.

The results of gravity observations made at Melbourne so far are given in a paper read by Mr. Baracchi before the Royal Society of Victoria in November last, and are as follows:—

Assuming the absolute length of the seconds pendulum at Kew to be ... ... 39·14008 inches

Assuming the absolute length of the seconds pendulum at Greenwich to be ... ... 39·13734 „

and using the mean result given by the three Invariable pendulums:

Value of g for Melbourne, taking Kew as basis ... ... = 32·14827 feet

„ „ „ „ Greenwich as basis ... = 32·14645 „

„ „ „ by Professor Neumeyer's absolute determination in 1863 ... ... = 32·15172 „

Value of g for Melbourne, by Lieut. Elblein's differential results, taking Vienna as basis with $g = 9{\cdot}80866$ metres, as determined by Professor Oppolzer in 1886 ... ... = 32·15317 „

Sydney Observatory.

Staff.—During the year 1893 no change in the staff has taken place, Mr. Lenehan and Mr. Sellors being astronomical assistants, and Mr. Savage, Mr. Hunt, and Mr. Noble meteorological assistants. Mr. Sloman computer, and three juniors for meteorological work.

At the beginning of the year, additions to the staff were contemplated for the extension of the meridian work and measurement and reduction of photographs, but the financial crisis which overtook the Colony in March effectually barred the increase for the present, as well as the publication of several volumes of astronomical work which are ready for the printer. It is hoped that this difficulty will soon pass away.

Transit Circle.—The weather during the year has been rather better than it was in 1892; counting all fine or partially fine nights we had 150. With the Transit Circle 1,453 transits have been taken; of these, 765 were of stars for our photographic zone, and these were also observed in declination. 279 star transits

and 433 of the Sun's limb were observed for adjustment of instruments, and for public time.

Azimuth was determined	...	...	...	...	89	times
Collimation	„	...	...	...	...	290	„
Level	„	...	...	...	...	373	„
Nadir	„	...	...	...	...	363	„

The stars observed in 1890 have been catalogued, and are now ready for the printer, together with those for the years 1882 to 1889 inclusive. The catalogues of 1891 and 1892 are nearly complete. The printing of the volume for 1879, 1880, and 1881 has been completed, and the book has been distributed.

No longitude or other outside work has been done with the Transit Circle this year.

Equatorial.— Of the ninety-nine nights fine enough for using the equatorial in the early part of the evening, the atmosphere was so unsteady on twenty-eight that no measures could be taken; during the year, 123 measures of double stars, each consisting of four measures in angle and four in distance, were obtained. Special observations of *α Centauri* were made for Professor See, and of *β* 416 for Professor Glasenapp. Only three new double stars were found during the year. Observations were made on seven nights for a redetermination of the value of the micrometer screw; all the double-star measures are reduced, and nearly ready for press.

Photographic.—When the guide-star list for our zone was made up, it was found that in many places there were no known stars. Stars have now been found and observed for all of these except four.

For the photographic survey work 161 nights have been wholly or partially fine enough for work. The forced economy in plates has necessitated the use of some fine nights in long exposures on places requiring special investigation with the camera, and these have been successful in bringing to light much valuable information. 311 catalogue plates have, however, been secured; 50 chart plates, exposure 1 hour; 51 exposures for several hours, and 65 others for various purposes, *e.g.* for test plates, for distortion, and for determination of scale values; in all, 477 photographs have been taken, of which 311 had each 3 exposures. Some of the plates for scale values had 34 exposures on *α Centauri* in different parts of the plates.

The star camera is used all night when possible, hence more nights are available than for the other instruments, which are only used in the evening.

Meteorology.—The weather-chart service, with two daily forecasts and weather charts, has been steadily maintained, and is adding materially to our knowledge of weather laws. The general meteorological service shows an increase of stations up to 1,260. The monthly general abstracts up to August have

been printed and distributed. The rain, river, and evaporation report for 1892 has been printed, and in part distributed. A new rain map, showing average rainfall on each square degree of the Colony, has been printed and distributed. The general meteorological results, 1891 and 1892, are waiting for the printer. The rain report and general results for 1893 are nearly ready.

General.—During the year upwards of 1,100 volumes, annual reports, serials, and pamphlets, have been received from other observatories or by purchase. In return, the astronomical results, the volume for 1891–92 and 1893, rain report for 1891 wholly and that for 1892 in part, have been distributed, with monthly and other publications, bringing up the total number to 4,015.

The number of visitors to see the observatory is becoming a serious item in our annual work. About 200 persons called on scientific business, and 632 to see the observatory; no fewer than 87 persons asked for information by letter, which occupied in preparation of replies 210 hours. This is a serious task on the time of our small staff, for which the implied compliment is poor compensation.

On May 8 the Navigating Lieutenant of the Austrian man-of-war *Kaiserin Elizabeth* came to the observatory and swung a set of three half-second pendulums, in the same part of the cellar that the Kater pendulums were swung in 1882 by the American transit of *Venus* observers, Professors Smith and Pritchard; and on July 3 the Navigating Lieutenant of the Austrian man-of-war *Saida* came with a duplicate set of three half-second pendulums and swung them in the same place.

Instruments.—In March it was found that the packing of the star camera object-glass had worn away, and that the lenses moved as the instrument turned with the clock, causing double images of the stars on the plates. The objective was taken out and new packing put in, and the double images disappeared. In other respects the instrument continues to give great satisfaction.

In June a new method of taking make or break seconds contacts from the pendulum was designed, and one was fitted to the pendulum in October. It is found a great improvement, avoiding, as it does, the errors of spacing in the clock-wheels; it moreover gives a quicker and surer contact, and disturbs the rate of the clock less than the old one did.

In June a new microscope for reading the declination circle of the 11½-inch equatorial was placed in position; by means of it one looks through the tubular polar axis and through two prisms on to the circle. The telescope can now be set in declination in half the time it used to take. The electrical wires on this instrument were renewed at the same time.

At the beginning of the year a mounting for the 6-inch star camera, then partly made, had to be put on one side, owing to the necessity for retrenchment, but it is hoped that this may be taken up again soon.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales.

It is gratifying to find that the work done at this observatory during the year 1893 bears favourable comparison with that accomplished in former years. The local sidereal time was determined on 153 nights, the number of stars observed for this purpose with a declination not exceeding 40° being 899. The separate determinations for level, collimation, and azimuth were 353, 42, and 151 respectively. No adjustment has been made of the transit instrument during the year, and the fluctuations of the instrumental errors have been smaller than usual. The rate of the standard sidereal chronometer has been good.

The following is a summary of the extra-meridian work:—With the two equatorials twenty-eight disappearances of stars were observed at the Moon's dark and five at the bright limb, and seven reappearances at the dark and five at the bright limb; altogether forty-five phases. Most of the stars have been identified, and nine *Nautical Almanac* stars were observed in both places. Interesting phenomena were presented at the disappearance of τ^1 *Arietis* on January 26, the particulars of which were given in Vol. III. page 187 of the *Journal of the British Astronomical Association*. It is very desirable that this star should be examined with powerful telescopes, as it is probably a triple one. I desire here to acknowledge the kind assistance of Mr. R. T. A. Innes, F.R.A.S., of Sydney, who has again supplied me with prediction calculations for the principal *Nautical Almanac* stars occulted at the observatory.

An excellent series of filar micrometer comparisons of *Saturn* with γ^1 *Virginis* was obtained on April 3, 4, 5, 6, 8, 10, 11, with the 8-inch equatorial. The results have been published in the *Monthly Notices*, and the tabular corrections for the planet are closely accordant with those obtained at the Royal Observatory, Greenwich, on April 10, 12.

The occultation of *Saturn* and *Titan* on May 25 was observed with the 8-inch telescope under excellent conditions, and the results were at once forwarded to the Astronomical Society of the Pacific. Minor Planets *Hebe* (6) and *Parthenope* (11) were observed with the filar micrometer of the 8-inch equatorial as follows:—*Hebe* on October 27, 29, November 1, 2, 4, 5, embracing seventy-five comparisons and three comparison stars; and *Parthenope* on September 20, 21, 22, 23, 24, 25, 29, embracing 106 comparisons and four comparison stars. These observations have been forwarded to the *Astronomische Nachrichten*.

It has been already notified in the Report for 1892 that Comet VI. (Brooks) 1892 was observed from November 28 to the close of that year. The observations have, however, been carried on, with occasional interruptions from moonlight and cloudy

weather, till June 19. The complete series of observations comprises sixty-two nights, 670 comparisons, and eighty-nine comparison stars, and is to be found in Nos. 3176, 3180, and 3189 of the *Astronomische Nachrichten*. Dr. Ristenpart's parabola represents very closely the whole series of observations. Comet 1893 II. (Rordame-Quénisset) was observed with the 4½-inch equatorial on July 29, 30, August 1, 3, 5, 6, 7, 8, 11, 12, 13, the number of comparisons being sixty-seven, and that of the comparison stars sixteen. The results have been sent to the journal just referred to.

At the request of Professor See, of Chicago, a series of measures of *α Centauri* was obtained with the 8-inch equatorial on ten nights, six east and four west of the meridian. The measures have been sent both to Professor See and to the *Monthly Notices*. In consequence of the pressure of other work no other double stars were observed.

On November 1 a paper was communicated to the Royal Society of New South Wales, pointing out that, in consequence of a remarkable coincidence of astronomical conditions, extraordinarily high spring-tides might be expected to follow immediately after the full moon of 1893 December. Although the tides along the coast of New South Wales were remarkably high, they did not come up to the expectations, owing, doubtless, to the interference of causes of a more strictly meteorological character.

The usual meteorological observations have been carried out through the year with great regularity. A meteorological record has therefore been secured at this observatory extending over a period of thirty-one years.

A considerable relaxation will be made in the astronomical work for 1894, but the meteorological work will be carried on as heretofore. The author of this report feels that a temporary rest is necessary. His labours have been peculiarly trying in consequence of the large amount of *morning* comet work undertaken during the past two years. In conclusion, he desires to thank all those contributors, both public and private, who have helped to enrich the observatory library, and his only regret is that, being a private observer, he is unable to meet their donations with exchanges of equal value.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets.

Thirty-four new minor planets were discovered in 1893, making a total of 385. The discoveries were all by photography with the exception of No. 369. The following is the list of discoveries:—

Provisional Designation. 1893.	Permanent Number.	Date of Discovery, 1893.	Discoverer.	Place of Discovery.
A	354	Jan. 17	Charlois	Nice
B	352	12	Wolf	Heidelberg
C	...	16	,,	,,
D	...	18	Charlois	Nice
E	355	20	,,	,,
F	353	16	Wolf	Heidelberg
G	356	21	Charlois	Nice
J	357	Feb. 11	,,	,,
K	358	Mar. 8	,,	,,
M	...	10	,,	,,
N	360	11	,,	,,
O	...	11	,,	,,
P	361	11	,,	,,
R	362	12	,,	,,
S	363	17	,,	,,
T	364	19	,,	,,
U	...	19	,,	,,
V	365	21	,,	,,
W	366	21	,,	,,
X	...	21	Wolf	Heidelberg
Y	...	Apr. 14	,,	,,
AA	367	May 19	Charlois	Nice
AB	368	19	,,	,,

Provisional Designation.	Permanent Number.	Date of Discovery, 1893.	Discoverer.	Place of Discovery.
1893.				
AC	370	July 14	Charlois	Nice
AD	371	16	,,	,,
AE	369	4	Borrelly	Marseilles
AH	372	Aug. 19	Charlois	Nice
AJ	373	Sept. 15	,,	,,
AK	374	18	,,	,,
AL	375	18	,,	,,
AM	376	18	,,	,,
AN	377	20	,,	,,
AO	...	Nov. 6	Wolf	Heidelberg
AP	378	Dec. 6	Charlois	Nice

No planet is now given a permanent number till five observations are available, which is the reason of the gaps in the column of permanent numbers. The discoveries of 1892 not numbered at the date of the last Report have been numbered as follows:— O 345, P 346, Q 347, R 348, T 349, U 350, V 351. S is omitted, not having been sufficiently observed. (314) has been named *Rosalia*, (316) *Roberta*, (317) *Roxana*, (334) *Chicago*, (344) *Desideratu*, (349) *Dembowska*. None of the planets discovered in 1893 have yet been named.

The planets provisionally named 1893 L, Q, Z, AF, AG were found to be identical with (89) *Julia*, (104) *Clymene*, (175) *Andromache*, (158) *Coronis*, and (107) *Camilla* respectively. In the case of *Julia* the number (359) had been assigned before the identity was discovered; an error in the *Berliner Jahrbuch*, combined with the unexpected brightness of the object, prevented its identity from being detected sooner. It has also been found by Dr. Berberich that (330) *Ilmatar* is identical with (298) *Baptistina*. To avoid confusion the subsequent numbers will not be altered, but (330), (359) will remain blank for the present.

The letter H 1893 is absent, since it was found that the planet thus designated was identical with G. With regard to these provisional letters, it has been decided for the future to make their sequence consecutive from year to year instead of beginning afresh each year; thus the first discovery of 1894 is A Q, not 1894 A. (363) is the same planet as that discovered photographically by Wolf, 1891 November 28, but not numbered at that time.

Photography has done good service in recovering long-missing planets, as well as in discovering new ones; among others (163) *Erigone*, (175) *Andromache*, (228) *Agathe*, (275) *Sapientia*. The previously accepted elements of *Andromache* gave an aphelion distance of 4·70 (one of the greatest of the family), but new elements, deduced by Dr. Berberich with the

aid of last year's observations, reduce it to 3·87. From these new elements he found that *Andromache* must have been near (325) *Heidelberga* at the time of the discovery of the latter (1892 March 4); and on re-examining the plate *Andromache* was found close to the computed place, thus confirming the accuracy of the new elements.

All the planets discovered previously to 1890 have now been observed at more than one opposition with the exception of the following:—(99) *Dike*, (132) *Aethra*, (155) *Scylla*, (156) *Xanthippe*, (157) *Deianira*, (188) *Menippe*, (193) *Ambrosia*, (220) *Stephania*, (285) *Regina*. A photographic search was made for *Xanthippe* at Heidelberg, but without success.

(361) appears to have the greatest aphelion distance, 4·76, of the whole family, while its mean distance is second only to that of (279) *Thule*. (353) appears to have the greatest eccentricity, 0·35, of the whole family, while the inclination of the orbit of (372) is second only to that of *Pallas*; but all these results are somewhat uncertain till the planets in question are observed at a second opposition. (372) is brighter than most of those discovered in recent years, and will probably be brighter than the ninth magnitude when in opposition near perihelion, which will be the case in 1894. A. C. D. C.

Comets of 1893.

The year 1893 has witnessed the discovery of only two comets and the reappearance of Finlay's periodic comet. But, in addition to these, it may be mentioned that comet 1892 I. (Swift) was still visible in large telescopes at the beginning of the year, while 1893 I. (Brooks) and 1892 III. (Holmes) could both be followed with moderate aperture. Comet 1892 IV. was also probably visible in the Southern Hemisphere.

(*a*) A return of Finlay's Comet. Excellent ephemerides had been prepared by M. Schulhof to assist the search for this comet, and, as a matter of fact, the early observations of Mr. Finlay showed that the error in the predicted time of perihelion was only about 0·62 day. This was the principal cause of an error in the computed place of May 17, the date of discovery, of seven minutes in R.A. and twelve minutes in Declination. The comet was described as one minute in diameter, and shining as an eleventh magnitude star, with no tail. The number of observations secured was not very large, for the comet remained an inconspicuous object, and was not very well situated for observation; for though it rose in July and August some three or four hours before the Sun, yet when it was high enough to observe, it was seen projected on a background in which the twilight was already noticeable.

(*b*) A comet independently discovered by several observers, but apparently first seen by Mr. W. E. Sperra, of Randolph, O.,

on June 19. This gentleman believed the object to be Finlay's Comet, and under that impression did not announce it. The comet was also seen on July 5 by M. Rosa de Luna, in Estremadura; but it was not till July 9 that its discovery was generally known, due to an observation by M. Quénisset, of the Juvisy Observatory, though Mr. Rordame, of Utah, had announced the comet in America on the previous day. Mr. Sperra followed the comet through *Aries*, *Taurus*, to *Auriga*, but accurate places are limited to the passage through *Lynx*, *Leo*, and *Coma*. The comet was followed at many observatories, till it disappeared in the Sun's rays. In the bright summer skies in this country the true dimensions of the comet were not appreciated. On July 11 Professor W. W. Payne, of the Goodsell Observatory, reported the tail to be 18° in length, extending to *β Ursæ Majoris*. A photograph taken of the comet on that night showed the tail to be 12° in length, but this distance was possibly curtailed by the size of the plate employed to receive the image. Considerably more detail is shown on the photographic plate than could be recognised by the eye, but this is a feature to which we are growing accustomed in cometary photography.

The spectrum was observed by Professor Campbell at the Lick Observatory, both visually and photographically. The agreement with the spectrum of carbon and cyanogen was found perfect, but the wave lengths of the cometary spectrum were systematically less by one or two tenth-metres. The observer suggests that this discrepancy may be explained by the motion of the comet relative to the Earth, but the low altitude of the comet, and the consequent approximately horizontal position of the telescope, caused some flexure in the spectroscope which might explain some of the discordance.

As the comet receded from perihelion it was picked up again by Dr. Cerulli on November 4, when it was a very faint object in a 15-inch refractor. The orbit is not yet definitely computed, but the observations are well satisfied by a parabola.

(*c*) Discovered by Mr. W. R. Brooks, of Geneva, on October 16. The comet was then in *Virgo*, and could only be seen shortly before sunrise, but its northerly motion soon brought it into a favourable position for observation. The perihelion passage had occurred nearly a month before the discovery, but as the comet was continually approaching the Earth, the diminution of brilliancy was very gradual. The discoverer thought the comet was at its brightest on October 21, when it exhibited a tail of $3\frac{1}{2}°$ in length. Professor Barnard could only trace the tail visually for 2°, but on the various photographic plates taken at Lick the tail could be traced fully 10°. Mr. Brooks noticed some divisions in the tail on October 21; but here, again, the photograph shows very considerable changes which could not be detected by the eye, while rapid and remarkable changes in position-angles of the tail are recorded on the plates.

The orbit is probably parabolic. The Rev. G. M. Searle, noticing some similarity between the elements and those of 1822 I. and 1864 I., sought to represent the observations by an ellipse, but found the deviations from the parabola to incline rather to the hyperbola.

Foremost among the discussions of orbits in the year should be mentioned the investigation by Mr. C. Lane Poor of the orbit of 1889 V. (Brooks), with the view of determining or disproving the comet's identity with that of Lexell, 1770. The research is based upon the work of Dr. Julius Bauschinger, embraces an accurate discussion of the perturbations of the orbit between 1889 and 1886, and gives the hyperbolic orbit in which the comet moved when submitted to the influence of *Jupiter*. With the most probable value of the mean motion, the author finds that the comet was within the system of *Jupiter's* satellites for 2·65 days, and made during that time nearly a complete circuit about the planet, passing over an arc of 313° of longitude. The nearest approach to the planet was on 1886 July 20–1, when it was separated only by a distance of 2·28 radii. Previous to the comet's approach to *Jupiter*, Mr. Lane Poor ascribes to the orbit a period of 31·38 Julian years, with an uncertainty of 1·2 years. This result differs some five years from that found by Dr. Chandler (*Astronomical Journal*, No. 205). The tendency of the research is to disprove the suggested identity of the comet with that of Lexell. This is shown both by the want of commensurability of the period with the interval elapsed since Lexell's comet underwent its great perturbation and the non-fulfilment of the Tisserand criterion. Dr. Schulhof had previously shown that an identity could not be supported, unless great perturbation from *Saturn* had been experienced; and Mr. Lane Poor shows that no approach to *Saturn* is probable. We must await the appearance of the comet in 1896 before a complete answer can be given to this interesting question of identity.

Besides the determination of the orbit of Finlay's Comet by Dr. Schulhof, already referred to (*Bulletin Astronomique*, 1893 April–June), definitive elements have been assigned to 1840 I., by Dr. Rechenberg, with the result that a long ellipse best represents the observations (*Ast. Nach.*, No. 3136); to 1890 III. by Dr. Ebert, who finds no deviation from a parabola (*Ast. Nach.*, No. 3151); to 1886 II. by Dr. Thraen, affording a case of hyperbolic motion (*Ast. Nach.*, No. 3160). Improved elements of 1892 III. are given by Mr. Corrigan, who assigns a period of 2,516 days (*Ast. and Ast. Phys.*, 1893 Dec.); and Messrs. Isham and Porter find that a parabolic orbit satisfies the observations of 1893 I. (*Ast. Journal*, No. 295).

The elements of the comet of 1811, with which Argelander's name is inseparably connected, have been recomputed by Dr. N. Herz. The results are given in the second volume of the publications of the Von Kuffner Observatory, and interesting

remarks on this discussion, by Dr. H. Kreutz, will be found in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, Jahrgang 28, Heft 4. W. E. P.

Total Solar Eclipse of 1893 *April* 16.

The final reports of this eclipse will be summarised later. For a report on the English expeditions, see *Monthly Notices*, vol. liii. p. 472.

The Fifth Satellite of Jupiter.

Observation of the satellite was carried on with the 36-inch at Mount Hamilton in 1892 until November 20, by Professor Barnard.

After this date Professor Barnard did not succeed in getting any observations of the satellite until 1893 January 5. It was then excessively faint, but the observations were good, the seeing being first-class. It was also seen on January 8, for the last time during that opposition of *Jupiter*. The satellite was first seen, during the present opposition, on 1893 September 3, and again, under better conditions, on September 15. Though fairly well seen it was very faint. The time of east elongation obtained from the measures on September 15, which was 8 minutes slow of the time given in Marth's ephemeris (*Monthly Notices*, vol. liii. No. 8), combined with the elongation of 1892 September 10, gives for the period the value $11^h\,57^m\,22^s{\cdot}56$, which is $0^s{\cdot}50$ less than the value deduced from the 1892 observations, and $0^s{\cdot}68$ greater than Marth's value. The measured equatorial diameter was $44''{\cdot}34$, corrected for phase by the aid of Marth's ephemeris.

Some observations by Professor Young and Professor Reed at Princetown, October 7, confirm the Lick results.

The satellite has also been seen with the great refractor at Pulkowa, and was first observed there about midnight on 1893 October 21, at east elongation, very near the place indicated in Marth's ephemeris. Dr. Hermann Struve in *Astronomische Nachrichten*, No. 3200, states that the satellite could be measured to within about $10''$ from the eastern limb of *Jupiter*, and could be still recognised to within $5''$ or $6''$ from the limb. The measures could easily be made with dark wires, owing to the illumination of the field by diffuse light from the planet. Dr. Struve estimates the satellite to be fainter than *Mimas*, but brighter than *Hyperion*, which latter object at an equal distance—$10''$ to $15''$ from the limb—was quite as difficult of observation, though the brightness of the field is much less in the case of *Saturn* than of *Jupiter*. The agreement in the measures made during the two hours which

elapsed between east elongation and the satellite's approaching to 10″ from the E limb is stated to be very satisfactory, enabling a good estimation of the longitude and time of east elongation to be deduced. Compared with Marth's ephemeris, the correction for longitude is $\Delta l = -4°{\cdot}3$, while for the east elongation of October 21 was found $a = 60''{\cdot}0$ nearly. The period deduced would thus be about $0^s{\cdot}70$ greater than Marth's. A. E.

Nova Aurigæ.

During the past year the *Nova* has remained of about the 9th magnitude, and certainly has shown no such sudden and frequent changes of brightness as were recorded in the Council's report for last year. A change of about 1 magnitude, however, was observed by M. Bigourdan in October. On 1893 October 10 M. Bigourdan estimated the *Nova* as $1\frac{1}{2}$ magnitude brighter than the star 85″ *n.f.*, but on November 8 the *Nova* was found to have fallen below this star in brightness, while three days later it was again brighter than the star, but not to the unusual extent observed on October 10.

M. Bigourdan took a series of micrometric measures of the distance of the *Nova* from the star 85″ *n.f.* during October and November for comparison with a set of similar measures which he made, not very long after the first appearance of the star, during 1892 February. The close accordance of the two sets of measures shows that no change of position of the *Nova* relatively to this star had taken place in the interval.

The observations of the visual appearance of the *Nova* since it was reobserved in the autumn of 1892, as made at different observatories, are not in good agreement. At the Lick the *Nova* presented the appearance of a small bright nebula, consisting of a nucleus surrounded with a pretty bright and dense nebulosity, 3″ in diameter. On the contrary, Mr. Newall, observing with the 25-inch Newall refractor on 1892 September 14, found the *Nova* to be truly stellar when the telescope was specially focussed upon it. At Pulkowa it was seen as a small nebula. At Upper Tulse Hill, when viewed in the Cassegrain reflector of 18-inch aperture, the *Nova* appeared as truly stellar as the small star near it. Professor Vogel and Mr. Newall have suggested that a possible explanation of the nebulous appearance observed at the Lick Observatory and at Pulkowa may be found in the chromatic corrections of those telescopes, which they considered would be sufficient to account for such an appearance in an object of which the greatest part of its light was near λ 5000, if the telescope had been focussed upon the neighbouring stars.

In 1893 February, Dr. and Mrs. Huggins found in the spectrum of the *Nova* the two bright bands, which had been regarded as the nebular lines, to be, unlike these, not narrow,

defined lines, but groups of bright lines extending in the case of the principal group through about fifteen tenth-metres. They, therefore, find it difficult to suppose that the same substance or substances which produce the nebular lines—notwithstanding possible different temperatures, or even allotropic conditions—also give birth to these complex groups.

Professor Campbell, following up the photographs of Herr E. von Gothard mentioned in the report of last year, has compared the spectrum of the *Nova* as obtained by visual observations and by photographs with those of five nebulæ, and regards nineteen lines in the *Nova* (including the lines of hydrogen, which are, however, common to nebulæ and to stars) as probably identical with lines in the spectra of the nebulæ. Professor Campbell has continued his measures of motion in the line of sight from the estimated middle of the bright bands in the *Nova*, as compared with the wave-lengths of the nebular lines as determined by Professor Keeler. The motion which he thus obtains he finds to be in agreement with the apparent shift of the hydrogen lines.

An important discussion of the phenomena of the *Nova* by Professor Vogel has appeared ("Ueber den neuen Stern im Fuhrmann") in which Professor Vogel gives in detail all the observations made at Potsdam, and also a review of the principal hypotheses which have been suggested to account for the outburst and the remarkable changes of this star. Professor Vogel attaches importance to the fair agreement of the positions of the bright lines in the *Nova* as determined at Potsdam, with those which Professor Young assigns to the brightest lines of the chromosphere. Professor Vogel points out objections to the view which Professor Seeliger takes, that the phenomena of the *Nova* may be due to a heavenly body entering a cosmic cloud, and criticises the objections based upon the rapidity of their separation, which Professor Seeliger raised to the hypothesis of enormous tidal action caused by a very near approach of two bodies. Gigantic oscillations might well last for months, especially if, as is very probable, one or both bodies had come into a state of unstable equilibrium through an advanced state of cooling.

Professor Vogel concludes in favour of a modification of this view so far as to suppose, which is very probable, that one of the bodies is surrounded with a system of planets resembling the solar system, though it may be on a much larger scale. He thinks that in the disturbances set up during the passing of a body through such a system, we should find an adequate explanation of the phenomena presented by the new star.

There has since appeared a reply by Professor Seeliger (*Ast. Nach.* No. 3,187); but in a recent short note (*Ast. Nach.* No. 3,198) Professor Vogel says that, though he maintains unchanged the position he had taken up in his Paper on the *Nova*, he has no wish to enter at present into further discussion on the points raised by Seeliger.

The time has not yet come for a final discussion of the remarkable phenomena presented by the *Nova*. It may be that light will be thrown on some of these at least, by the continued study of the spectral changes of *β Lyræ* and of similar variables, in which dark and bright lines of the same substances appear to undergo periodical relative change.

Variable Stars.

Dr. Chandler's Second Catalogue of Variable Stars will be welcomed by all who take an interest in the subject. A skilled observer as well as an able theorist, his work commands every confidence and respect.

Judiciously severe in his treatment, he only admits into his catalogue stars as to the variability of which there is no doubt; he gives, however, in addition, a "List of Unconfirmed Stars," which invite further investigation and work. The arrangement of the catalogue is very complete in respect of the place, colour, limits of range, period and epoch, and terms of inequality, while interesting particulars are added in the notes. In the introduction, in which Dr. Chandler warmly recognises the help he received from others, are to be found full particulars in regard to the catalogue, and, further, some very interesting and suggestive remarks as to several of the phenomena presented by some of the long-period variables in respect of periodic cycles of variation. The catalogue, which is marked by the true scientific spirit, must have involved a great deal of labour in its preparation, and those who are interested in this line of work must feel deeply indebted to the author. G. E.

There has been an encouraging degree of activity in the observation of the phenomena of the variable stars. Among the more important of the series of such observations which deserve special mention are those of Dunér at Upsala (291); of Roberts, in South Africa, whose zeal and activity have a peculiarly valuable field in perfecting our knowledge of the variables in the southern hemisphere; of Townley, at Madison, whose work has been especially directed to the phenomena of the minima of the telescopic variables, a direction in which our knowledge is still in arrears; of Parkhurst, at Brooklyn, whose publication of the results of his last ten years' work forms so noteworthy an addition to our fund of material; and of Yendell, at Boston, whose industry and intelligent work place him in the forefront among contributors in this field, not only in the persistent following of the known variables, but in the labour of bringing order out of the chaos into which our knowledge is continually threatening to drift, by critically examining the larger number of alleged and suspected cases of variability which flood the scientific periodicals.

One of the most interesting investigations on variable stars, tending to perfecting our knowledge of their causes, is that of Dunér on Y *Cygni*. It will be remembered that Dr. Chandler, soon after his discovery of its variability in 1886, signalised the existence of some extraordinary anomalies in its behaviour, which seem to have no counterpart among the other variables now known; and after observing it several years, he was unable to ascertain the true laws which govern the phenomena, although his subsequent observations, as well as those of other astronomers, confirmed the existence of these singular perturbations of its light-variations. Dunér, however, took up the subject, and ultimately reached an explanation of them which, although still subject to some objections and uncertainty, does undoubtedly, on the whole, point to a cause which is a real one, although it may prove to be an expression of a half-truth. Nevertheless, his theory is one of the most ingenious and brilliant results which the history of these objects has developed.

Without going into the details of the phenomena to be explained, it is sufficient to say that his hypothesis is that, in the case of this variable, we have a star with two components of nearly equal brightness, revolving in the observer's plane, so that in the course of a single revolution we shall have a double occultation; and further that, the orbit being elliptical and the line of apsides lying at an angle to the line of vision, the intervals between these occultations are unequal. Again, since observation shows this inequality is not a constant quantity, we have reason to presume that this line of apsides is in motion.

This explanation meets the observed facts so well in general, that Dunér's hypothesis has a high degree of probability. But there are some facts, not yielding to this general explanation, which would apparently indicate to a cautious mind that the hypothesis may be, as has been said above, but the expression of a half-truth. Nevertheless, the discoveries connected with this variable form a most important episode in our knowledge.

Not less important is Professor Arthur Searle's confirmation, by observation with the meridian circle of *Algol* and the neighbouring fundamental stars of the irregularity in the proper motion, of that variable indicated by the theory of which an account was given in the last Annual Report.

Professor Searle, by a series of purely differential meridian-circle observations, very carefully and elaborately discussed, shows that the Right Ascension of this star is now increasing in accordance with Chandler's theory, the amount of the increase since 1885 being slightly greater than that assigned by that theory. As is known, the assumption of uniform proper motion would require it to have slightly decreased in the same interval. The amount of the difference cannot possibly be attributed to error of observation. The result of Searle's work must be regarded as a distinct confirmation of the orbital motion of the theory in question.

New Variable Stars, &c., discovered at Harvard College Observatory.

VARIABLES.

Constell.	R.A. 1900. h m	Dec. 1900. ° ′	Magn.
Columba	5 47·2	−29 19	7·9 to fainter than 11·4
Scorpius	16 56·8	−36 40	9·2 to fainter than 12·9
Pavo	18 3·3	−63 38	7·6 to 9·0

TYPE IV.

Design.	R.A. 1900. h m	Dec. 1900. ° ′	Magn.
B.D. +49° 41	0 12·2	+49 44	9·4
A.G.C. 5429	4 43·8	−36 23	7½
„ 6519	5 31·7	−25 48	8
„ 8670	6 51·3	−42 14	6·7
„ 11890	8 42·4	−29 21	7½
„ 13665	9 56·7	−59 44	7½
„ 19745	14 29·5	−42 56	8½
B.D. +9° 4369	19 56·3	+ 9 14	8·7
B.D −21° 6376	23 6·3	−21 32	9.0

TYPE V.

Design.	R.A. 1900. h m	Dec. 1900. ° ′	Magn.
13554	9 51·6	−57 15	8½
...	10 6·1	−62 5	...
...	10 13·3	−57 24	...
...	10 14·4	−62 9	...
...	10 22·9	−58 8	...
...	10 47·9	−61 46	...
...	11 55·2	−54 33	...
...	13 24·3	−61 34	...
...	15 55·0	−62 28	...
22838	16 47·9	−44 50	8·2

Stars having F line bright.

B.D. −13° 893	4 24·5	−13 17	5·8
„ −10° 1786	6 53·2	−10 38	7·3
Nova Normæ	R.A. $15^h\ 22^m\cdot2$	Dec. −50° 14′ (1900)	

All of the stars in the above lists were found by Mrs. Fleming, except A.G.C. 11890, which was found by Mr. A. E. Douglas.

New Double Stars, discovered in 1893, *and measures, by Professor G. W. Hough, at the Dearborn Observatory.*

Star.	R.A. h m s	Decl. ° ′	P °	D ″	M	1800+	
Lal. 6233	3 17 23	+45 5	35·6	1·48	7·5...10	93·17	
D.M. +45°·764	3 17 46	+45 10	116·5	1·27	9 ... 9·5	93·28	
Lal. 18742	9 26 17	+28 54	255·6	32·46	6·5...11	93·28	
W. xv. 1359	15 54 54	+16 1	132·9	9·82	8 ...13	93·48	
W. Arg. 12990	16 53 39	−29 29	N.	10	8 ...13	93·54	
G. 23296	17 5 41	−38 9	148·9	3·14	7 ... 9	93·54	
G. 23306	17 6 9	−39 37	S.p.	15	6·5...10	93·54	
...	...	...	N.p.	15	10	„	
Σ 2191 = A.B.	17 33 25	− 4 54	267·3	26·41	7 ... 8	93·58	A.B.
...	...	...	32·7	8·34	8 ...12	„	A.C.
D.M. +37°·2912	17 33 37	+37 3	103·4	1·03	9·2... 9·5	93·46	
S.D. −5°·4517	17 46 17	− 5 17	19·8	0·48	8·2... 9	93·60	
G. 24715	18 2 39	−29 14	80·3	0·74	8 ... 8	93·54	
S.D. −14°·5096	18 25 21	−14 5	41·7	0·88	9·5... 9·5	93·65	
Lal. 35076	18 46 6	−18 47	N.f.	12	7 ...11	93·76	
D.M. +24°·3673	19 7 27	+24 23	244·5	4·78	9 ...10	93·68	
W. xix. 193	19 7 43	+24 22	45·4	5·69	8 ...12	93·68	
Anon.	19 11 22	+27 43	181·0	1·14	9·5... 9·5	93·80	
D.M. +18°·4621	20 43 2	+18 27	359·5	0·55	9·3...10	93·69	
W. xxii. 262	22 12 25	+17 49	287·8	16·70	8 ...11·5	93·79	
D.M. +25°·4776	22 31 32	+26 6	221·8	6·49	7·5...13	93·83	
Lal. 47150	23 56 36	+35 9	f.	18	7 ...12	93·86	

Struve's Double Star Measures.

The tenth volume of the Pulkowa Observations contains work done during the directorate of M. Otto Struve, and principally by himself. The two volumes, IX. and X., contain the whole of his measures of double stars made in the period 1839–1889. We thus have continuous measures by the same observer for fifty years.

The work of the volume is divided into four sections:

(1) Double stars in Herschel's Classes V. and VI.
(2) Stars with large proper motion.
(3) Stars discovered by Burnham and other astronomers.
(4) Measures of Σ and O Σ stars.

Section I. contains measures of 113 pairs. The measures, 495 in number, extend only to the year 1882; and of these 357 were made by O. Struve with the 15-inch refractor, and the remaining 138 by M. Doubiago with a 6·2-inch refractor. Notes are appended to each star, embodying the general conclusions deduced from the observations, and in many cases also giving previous measures.

Most of the observations in Section II. were commenced in 1850, and followed in natural sequence to those made for the parallax of Groombridge, 1830. About 240 stars were selected from Argelander as having an annual proper motion greater than 0″ 2. The vicinity of each star was examined to discover any small stars sufficiently favourable for micrometric measures. Sixty-five were thus selected, and afterwards the list was reduced to 140. The observations of this section are under the heads:

(1) Observations for parallax.
(2) Observations for relative motion.
(3) Observations to determine the proper motion of the small stars.

As a result of (3) a long list of proper motions is given, which ought to be of great utility.

Sections III. and IV. contain the continuation of O Σ measures, and are accompanied by a catalogue with references to both volumes IX. and X., so that much time is saved in knowing exactly where to look for the measures of a particular pair.

Solar Activity in 1893.

So far as the solar records of 1893 are as yet available, it would appear that we are still on the ascending branch of the Sun-spot curve, though the diminishing steepness of the curve suggests that the summit is not very far distant. The mean daily spotted area, as measured at Greenwich upon the solar photographs, was 100 millionths of the visible hemisphere, for 1890; in 1891 this had risen to 566, and in 1892 to 1,250—considerably higher than the highest registered during the last cycle, when the record for 1883, the year of maximum, was 1,155. So far as the data are as yet available for 1893, it appears that the mean daily spotted area for the year just past exceeded 1,400 millionths—a distinct advance, that is to say, on 1892, but by no means in the same proportion that the latter year exceeded 1891.

Professor Tacchini's observations fully confirm the Greenwich results so far as the spots are concerned; but whilst the latter show a considerable falling off in the areas of the faculæ, Professor Tacchini has registered a distinct increase. Both

records, however, agree in marking the month of 1893 August as the heaviest in the present maximum, so far as the spotted area is concerned, and not only so but as heavier than any month of the previous period. Professor Tacchini finds 1883 July the heaviest month of the last cycle with the "comparative extent" for spots of 224·89, whilst 1893 August gave 227·5. For the faculæ Professor Tacchini makes 1893 September the heaviest month, with comparative extent 134·0; the highest record for the previous maximum being that for 1882 November, comparative extent 127·48.

In one respect, 1893 has proved inferior to 1892; there has been no single group of dimensions to equal those of February 1892. There have, however, been several exceedingly fine groups, and those of August 1–13, and November 16–28, have been quite equal to the very largest groups of the preceding maximum.

A most significant indication of the progress of the cycle is the gradual transference of the chief Sun-spot activity to the lower latitudes. This downward drift of the mean latitude of the spotted area has been very noticeable in both hemispheres, but especially in the northern, in which the mid-cycle latitude has been nearly reached. The balance of distribution between the two hemispheres, which was slightly in favour of the northern in 1892, has shifted over very decidedly to the southern in 1893, a change which in the preceding cycle took place about a year before the point of maximum was reached.

Solar Prominences in 1893.

The year 1893 has not been marked by very exceptional activity in prominence formation, judging by the records that have come to hand so far. Indeed, Mr. Evershed reports that the two previous years seem to have been more productive of brilliant metallic eruptions and great outbursts than last year; whilst Professor Tacchini's results also show a distinct falling off as to mean number, height and extent of the prominences of 1893 as compared with those of 1892. His figures for the last three years are as follows :—

	1891.	1892.	1893.
Mean number	7·06	9·19	7·58
Mean height	40″·4	39″·6	37″·7
Mean extent	1°·7	1°·9	1°·8

Professor Tacchini argues that this decline in prominence activity, side by side with a considerable increase in the spotted area, furnishes a fresh proof that the two orders of phenomenon are not so intimately connected as was once supposed; and he

regards the falling off in the number of auroræ and great magnetic disturbances as confirming his old opinion that these terrestrial phenomena are connected rather with the phenomena of the chromosphere than with those of the spots.

Mr. Evershed finds, on comparing the total number of all classes of prominences observed with those of 1892, that the N. hemisphere has decreased considerably in activity, particularly in the high latitude zone +65/75, where only a very feeble display remains. The S. hemisphere, on the other hand, has increased by a nearly equivalent amount and shows a very pronounced maximum of activity in the zone −60/70. Thus, whilst the total activity remains nearly as in 1892, a considerable change has occurred in the relative distribution of prominences in the two hemispheres, the S. being ahead of the N. in the proportion of about five to four, whilst in 1892 an approximate equality prevailed, and in 1891 the N. took the lead.

Prominences reversing the D lines and the group *b* have been fairly numerous during the year, particularly in the southern spot zone; but these reversals have seldom been conspicuous, and other metallic lines have only been recorded on one or two occasions. Of eruptive prominences it appears that in a total of 167 days of observation only five were seen, four being S. and one N. of the equator.

Among the more remarkable displays observed may be mentioned an apparently continuous chain of quiescent prominences nearly encircling the S. pole, and, as far as it is possible to judge, confined within the zone −60/70. This singular procession of prominences first appeared on the E. limb (P.A. 177°) on September 22, and continued visible at this point for 3 weeks; 14 days from the first appearance the leading prominence began to appear on the W. limb (P.A. 230°), and during the following seven days, or rather on the 1st, 2nd, 6th and 7th days (observations not being secured on the other days), the E. and W. portions of the series were visible simultaneously.

Prominences, remarkable for their brightness and rapid changes of form, were recorded on April 26 +25°, June 25 +7° to −19°, both on the E. limb; also accompanying the great spot group of August when near the E. limb on August 1 and 2; and a very curious series of eruptive filaments was observed at Kenley, on August 14, over the same group when at the W. limb. Two prominences of most unusual dimensions were observed by Fr. Fényi at Kalocsa in September; the first, on September 19, attaining a maximum height of 8′ 18″; the second, on September 20, with a height of 11′ 30″·6. The mean velocity of ascent in this latter prominence was 345 kilometers a second. Finally, on December 25 and 26 a very brilliant and extraordinarily active prominence was seen on the E. limb at +20° to 30°. Its maximum height, according to Professor Tacchini, amounted to 141″·1, which it attained on December 26

at 11^h 47^m, M.T., Rome. Its highest speed of upward movement was 26 kilometres a second, of descent 109 kilometres.

J. E.

Photographing the Corona without an Eclipse.

Two fresh attempts have been made during the past year to accomplish this feat. Mr. G. E. Hale, having had a special form of spectro-heliograph constructed for him, tested it during the latter part of June on the summit of Pike's Peak, hoping that at that great elevation, and with the pure skies usually enjoyed there, the atmospheric glare might be so far reduced as to permit the corona to give evidence of its presence. Unfortunately numerous fires in the forests surrounding the Peak sent up vast volumes of smoke, and the sky was scarcely freer from diffused light than as seen from Chicago. The experiments, therefore, met with no success; but, the conditions being thus adverse, Professor Hale does not consider that his method has been sufficiently tested as yet.

M. Ricco at Catania employed Dr. Huggins' method, and secured halos resembling the corona in general appearance upon his plates. But four photographs taken during the eclipse of last April, which was partial at Catania, failed to show an evidence of the Moon cutting out these supposed coronal forms, so that it must be feared that they cannot be regarded as genuine.

Occultations during Lunar Eclipses.

In 1884 it was pointed out by Dr. Döllen of Pulkowa that the approaching total lunar eclipse of 1884 October 4 would afford an opportunity for observing the occultations of faint stars, and hence finding an accurate place and diameter of the Moon. The idea was an attractive one, lending interest to a phenomenon which had hitherto lacked the importance it seemed to deserve; and many observers responded to Dr. Döllen's suggestion, and did their best to note the times of disappearance and reappearance of the stars, of which he gave a list by circular. On the next occasion of a total lunar eclipse, 1888 January 28, Dr. Döllen again sent out his circulars, and even more observations were obtained than in 1884. The discussion * of the results has, however, been somewhat disappointing. Dr. Ludwig Struve finds that in 1888, when there was considerable residual illumination of the Moon, even at mid-eclipse, the fainter stars indicate a semi-diameter greater by about $0''{\cdot}6$ than the stars of

* *Bearbeitung der während der totalen Mondfinsternisse* 1884 Oct. 4 und 1888 Jan. 28 *beobachteten Sternbedeckungen durch Dr. Ludwig Struve.* C. Mattiesen, Dorpat. 1893.

about magnitude 6 to 8, which suggests systematic error due to the residual illumination. And though this was not the case in 1884, the diameters from bright and faint stars agreeing fairly well, Dr. Struve is inclined to think that his definitive result for the semi-diameter, 15′ 32″·645 ± 0″·044, may still be several tenths of a second in error.

Photometric Observations of Planets.

The eighth volume of the Publications of the Astrophysical Observatory of Potsdam contains an important Memoir by Dr. Müller on the brightness of the planets. His observations lead him to divide the planets into two classes, depending, most probably, on the amount and character of the atmosphere they possess. The one class comprises *Mercury*, the Moon, and the minor planets, which have probably little or no atmosphere; the other class, *Mars* and *Jupiter*, which certainly possess considerable atmospheres. The theories of Lambert, Lommel, and Seeliger, none of them precisely represent the facts of the case as Dr. Müller's observations present them, the observed brightness being greater than the theoretical at or near opposition, but less when there was a large phase. A straight line represented the empirical light curve pretty fairly, if, instead of the factor "quantity of light," its logarithm be taken.

Harvard College Observatory has published the results of a series of observations of variable stars and of minor planets, extending over ten years, made by Mr. Henry Parkhurst with a wedge photometer. Mr. Parkhurst concludes from his observations that every star is more or less variable, but that the Sun's light is practically constant; for when his observations of the asteroids are corrected for distance and phase they show a remarkable steadiness, and afford no evidence of a change in the solar brightness even to the extent of one per cent. during the whole period of observation.

The same volume, vol. xxix. of the *Annals of the Astronomical Observatory of Harvard College*, contains also a short appendix, giving a comparison of the results obtained by the two above-mentioned observers. Eleven asteroids are common to the two series of observations, and the comparison shows that both observers found that "the effect of the phases of an asteroid upon its magnitude is sensibly proportional to the angle determining the phase." The differences in the observed magnitudes of the asteroids, though often not inconsiderable, were not greater than might have been naturally expected when the difference between the methods employed to determine the scales is borne in mind. The accordance as to the phase co-efficients obtained by the two observers is very close for all the asteroids best observed, with the exception of *Massilia*.

M. Tisserand's "Traité de Mécanique Céleste," Tome III.

Short notices of tomes i. and ii. of M. Tisserand's work have appeared in former Annual Reports of the Council (*Monthly Notices*, vol. xlix. p. 216, and vol. li. p. 243); the third volume, recently published, now claims our attention.

It was M. Tisserand's original intention to complete his *Traité* in three volumes; he found, however, that lunar theory, to which the present volume is entirely devoted, claimed so much space for its adequate treatment that it would be necessary to relegate the other subjects not yet treated of, *i.e.* perturbations of minor planets and of comets, and the theory of satellites, to a fourth volume. The volume which is the subject of the present notice is of great interest and importance, not only to those astronomers who make lunar theory their special study, but also to that larger class who are desirous of having a handy reference book, written by a master of his subject, in which they may find a trustworthy historical account of the successive developments of the theory, as well as an epitome of the special researches which have been made, from time to time, by those who have most successfully devoted themselves to this difficult branch of gravitational astronomy.

The labours of Newton, the researches of the older French School, represented by Clairaut and d'Alembert, the great work of Laplace and of his immediate followers, are fully and impartially treated. Delaunay and Hansen claim, of course, a large amount of space, but those who have paid attention to special points in lunar theory, such as Hill and Adams, are by no means neglected. Perhaps the most interesting part of the book to practical astronomers is the chapter which treats of the present state of the theory. In it M. Tisserand points out the unsatisfactory state in which the lunar theory still is with regard to such matters as the secular acceleration and long-period inequalities; he dwells on Newcomb's corrections to Hansen's *Tables de la Lune*, by means of which a good agreement between computation and observation is obtained at the present time, and incidentally introduces the results of some researches of his own on the points to which he is directing the reader's attention. It is well that workers in this branch of astronomy should be thus pointedly reminded of the incomplete state of the lunar theory, and should constantly bear in mind M. Tisserand's concluding words, "il reste à faire une belle découverte!" A. M. W. D.

Harvard College Proper Motions.

An important contribution to the study of stellar proper motions has recently been published in vol. xxv. of the *Annals of the Astronomical Observatory of Harvard College*. This volume contains the results of the observations of stars in zone 50°–55° north declination, made with the meridian circle of the observatory, in connection with the *Astronomische Gesellschaft* Catalogue system during the years 1870–78 and 1883–84. The separate results reduced to the year 1875 are given at the end, and the mean results of each star are compared with observations given in any of thirty-two catalogues covering the period 1790–1880—that of Fedorenko's being the earliest—all carefully reduced to the epoch 1875. All stars which appear to have a progressive movement more or less well defined thus have their proper motions determined by comparing the places deduced from the various catalogues for the year 1875 with the position given by the Harvard observations for the same year, the time being the interval between the epochs. The adopted proper motions are the means of these several determinations, which are all separately given. In the introduction a table is also given of systematic corrections required to reduce the several catalogues to the system of the *Gesellschaft*. The observations were made and reduced under the supervision of Professor W. A. Rogers, who considers these values of the proper motions as provisional only, for the following reasons: First, because they depend upon the positions given in a single catalogue; secondly, because it cannot be assumed that the general system of the present catalogue is in exact accordance with that of the *Gesellschaft*; thirdly, because in those cases in which the data given depend upon only two or three authorities separated by short intervals of time, it is uncertain whether the apparent value of the proper motion may not be due to accidental errors; and, fourthly, because the various catalogue places, with the exception of those of Harvard, have been considered correct for the epoch of the catalogue instead of for the mean epoch of observation.

W. G. T.

The Cordoba Durchmusterung.

Dr. Thome, on succeeding Dr. Gould in 1885 as Director of the Cordoba Observatory, proposed to himself the task of continuing Schönfeld's Durchmusterung southwards, and he has now accomplished half his task, having completed the survey of the zone lying between 22° and 42° of South Declination. The catalogue for the northern half of this zone has been published

during the year, and forms vol. xvi. of the *Results of the Argentine National Observatory*, and it is to be followed shortly by vol. xvii., with the southern half of the zone, and by the atlas of twelve maps.

The number of stars in the two volumes is 340,380, giving an average of 56·1 for each square degree of the portion of the heavens mapped; whilst Schönfeld's average is only 18·5, and that for Argelander's Durchmusterung is 15·2. This great increase in the number of stars observed is due to Dr. Thome having adopted a higher magnitude, the tenth, as his limit; rendering thereby his undertaking a far more formidable one, but enhancing its value. The whole of the observations for this great enterprise, over 1,100,000 in number, were effected by two men—Dr. Thome and his assistant, Mr. R. H. Tucker—and were taken in about 1,600 separate zones, each usually of an hour's length, the one observer relieving the other at the end of each hour. The actual zone observations occupied about five years, and the reductions were kept up as closely as possible during the entire period. A careful revision was then undertaken which terminated about a year ago.

The zone observed overlaps those of Schönfeld by 1°, and a careful comparison of the magnitudes of the stars common to the two catalogues shows a satisfactory agreement as to scale.

Auwers's Re-reduction of Mayer's Observations.

Tobias Mayer was appointed Director of the Göttingen Observatory in 1756, and made observations there till his death in 1762, at the age of thirty-nine, being especially active during the years 1756 and 1757, when the city was besieged by an invading army. A catalogue of stars deduced from these observations by G. C. Lichtenberg was published in 1775, and proved their great value; and when Bradley's Catalogue appeared, Bessel compared the results of Mayer and Bradley in the *Fundamenta Astronomiæ*. In 1826 the Commissioners of Longitude published the original observations; and in 1831 Baily gave in the *Mem. R.A.S.*, vol iv., a new catalogue formed from the original observations, correcting many errors; and a new comparison with Bradley's observations.

The re-reduction of Bradley's observations, for which Dr. Auwers obtained the Society's medal in 1888, suggested to him the re-examination of Mayer's observations. He undertook this in 1877, but the pressure of other work necessitated its being executed by the help of several assistants. He has finally, however, completed it, and the result* is a sufficient testimony,

* Tobias Mayer's *Sternverzeichniss nach den Beobachtungen auf der Göttinger Sternwarte in den Jahren* 1756 *bis* 1760. Neu bearbeitet von Arthur Auwers. Leipzig, 1894.

if any were needed, to the skill of both the observer and his modern interpreter.

The daily and hourly rates of the clock (which was not compensated) have been carefully investigated; the instrumental errors, including an index error in Z.D. of 3″ to 4″, redetermined; and the proper motions discussed. The resulting ledgers of individual places almost bear comparison with modern observations; and the differences between Bradley and Mayer, which often exceeded 10″ in Baily's reduction, are reduced to a quarter or a fifth of this amount. The final catalogue and proper motions may thus be considered of the greatest value.

The Astrographic Chart.

The work for the Chart may now be considered fairly commenced. The second fascicule of vol. ii. of the *Bulletin du Comité Permanent*, which appeared towards the close of 1893, gives reports from seven of the associated observatories, stating the number of plates taken. For the Catalogue the total number obtained at these seven observatories is 1,731, the total number assigned to them on the definitive programme being 8,308. So that if the observatories which have not reported are as well advanced, there should be no difficulty in completing the Catalogue plates before the year 1900. Of Chart plates, however, only 415 have been taken by the same seven observatories, so that the date of completion of the long-exposure plates, even without duplication, is still uncertain.

The fascicule contains some important memoirs—one by M. Kapteyn on the distribution of the stars, his principal conclusion being that the light of stars in or near the Milky Way is richer in actinic rays than that of stars remote from the Milky Way; another by M. Lœwy on the measurements of the plates with a view to the formation of a catalogue; and a third by M. Prosper Henry on the practical reduction of measures of a photographic plate. A paper on this subject has also been published by Mr. Turner in the *Monthly Notices*.

Letters from directors of observatories, printed at the end of the fascicule, testify to the practical difficulties encountered by them, notably with the *réseaux*, the films of which seem peculiarly liable to perish, causing faults in the photographs.

Variation of Latitude.

Little that is quite new has appeared in connection with this interesting question during the year. Indeed, after Mr. Chandler's exhaustive analysis of old observations, we must rather look to the future for confirmation or modification of the law which he has

enunciated. One somewhat unexpected piece of evidence in favour of this law was discovered, or rather recovered, by M. Nyrèn. Finding that the results obtained with the Pulkowa vertical circle during the years 1882–1891 satisfactorily confirmed the period of 430± days, he re-examined some observations made in 1875–79 with the large transit in the prime vertical for determining the constant of aberration, which he had rejected on account of a change of o″·07 which was found to take place in the level of the axis, according to the position of the observer. These also are found to show the wave clearly; and by comparison of the maxima at this time with those in the period 1882–1891, periods are found to be very nearly thirteen years. The amplitude is more uncertain, as others have already found. Mr. Chandler has published an eighth paper on the subject, proving in detail the *direction* of rotation of the pole from west to east.

The observations made at Waikiki, near Honolulu, Hawaiian Islands, in the latter half of 1891 and first half of 1892, simultaneously with the Berlin, Washington, and San Francisco observations, have been published (*U.S. Coast Survey Bulletin*, No. 27).

As regards future observations, a Commission has been nominated, composed of MM. Tisserand, Förster and Schiaparelli, to draw up a programme of permanent observations to be made in different parts of the Earth.

The New U.S. Naval Observatory.

The new U. S. Naval Observatory is situated on Georgetown Heights, in West Washington, 280 feet above the level of the Potomac River; the dome on the western end of the main building being 10,295 feet N. 23°50′ W. of the small dome of the old Naval Observatory. The grounds, having an area of 69·8 acres, were purchased in 1881 May, but the contract for the erection of the buildings was not awarded until 1888 October, and vexatious delays on the part of the contractors deferred their completion until 1893 February. The architect was Mr. Richard M. Hunt, of New York, whose work in connection with the Columbian Exposition at Chicago is now so well known. The buildings, which all face truly north and south, divide themselves into four classes—viz., a large office building, a group of buildings containing the principal astronomical instruments, the photographic and magnetic buildings, and the boiler house, dynamo building, stables, &c.

The office building is of white marble, in the Italian style, having an extreme length north and south of 307½ feet, and for the most part a height of two stories. At its eastern end is the library room, circular in form, with an interior diameter of 48

feet, and a height of 40 feet; in the centre are the office and computing rooms, the record room, the chronometer rooms, and the rooms for the storage and exhibition of instruments not in actual use; while at the extreme western end are the tower for the 12-inch equatorial and the transit room for the time service.

The centre of the group of buildings which house the principal astronomical instruments is located on the highest point within the observatory grounds, 260 feet north-west of the western end of the office building, and at an altitude of 14½ feet greater. The centre of this group is the clock-room building, consisting of the clock-room itself and two wings, known respectively as the east and west observers' rooms. Thirty feet north of the clock-room is the prime vertical building, measuring 18 by 20 feet; and at distances of 26 feet, respectively east and west of the observers' rooms, are the east and west meridian circle buildings, each measuring 30 by 40 feet. 112 feet south of the clock-room is the 42-feet dome for the 26-inch equatorial telescope, with suitable offices attached for the use of the observers.

The photographic and magnetic houses are respectively 425 and 675 feet south by east from the clock-room. The boiler and dynamo houses, which supply water, electric light, and steam heat to the whole establishment, are situated 650 feet east of the clock-room, and the residence of the superintendent is 700 feet north-east of the same point.

Advantage was taken of the removal from the old to the new observatory to get all the instruments repaired and relacquered, and most of them were virtually rebuilt in accordance with detailed plans and specifications drawn up by officers of the observatory. The 26-inch equatorial has been provided with an entirely new mounting, considerably heavier than the old one, and the floor of its dome is arranged so that it can be elevated to any desired height by means of hydraulic pressure. So long as only ordinary micrometers and eyepieces are used on an equatorial, a stationary floor, together with a high observing chair, answer well enough; but the large spectroscopes and other heavy apparatus now so common can scarcely be safely handled on a high ladder, and for that reason an elevating floor is a great convenience, if not an absolute necessity, for large telescopes.

In the 25-feet dome, on the west end of the main building, a 12-inch equatorial mounting has been erected, to which the old 9·6-inch object-glass has been temporarily adapted; but, as soon as a 12-inch object-glass can be obtained, it is intended to remount the 9·6-inch equatorial in a small building of its own.

As the 26-inch mounting was constructed by Messrs. Warner & Swasey, and the 12-inch by Mr. Geo. N. Saegmüller, the mechanical details of the two instruments are quite different; but the various parts are so nearly equivalent that the following descriptive remarks apply to both:—The principal novelty in these instruments is a pair of dials which face the observer when

manipulating the quick motions, and indicate the right ascension and declination of the point to which the telescope is directed. By the side of these dials are the eyepieces of the long microscopes for reading the fine right-ascension circle, while the eyepieces of the long microscopes for reading the fine declination circle are at the eye end of the telescope. By means of a lever provided for the purpose, the rate of the driving clock can be readily altered from sidereal to either mean solar or mean lunar; and by a slight movement of a pair of prisms the light from a star which is being observed with the position micrometer can be instantly thrown into a direct vision spectroscope, situated near the finder of the telescope, without in any way disturbing the micrometer.

In the east meridian-circle building the old Pistor and Martins Transit Circle is mounted, but it has been remodelled by increasing the aperture of the telescope to 9 inches and diminishing its focal length to 9 feet; regraduating circle B, the original graduation having become illegible in some places; enlarging the openings in the central cube so as to permit the use of new horizontal collimators of 4 inches aperture and 48 inches focus; providing a vertical collimator of 4 inches aperture and 54 inches focus; and erecting a meridian mark, visible through a lens of 6 inches aperture and 375 feet focus. In the west meridian-circle room it is intended to mount a new Transit Circle of 6 inches aperture and 6 feet focus, which is now being constructed in accordance with specifications prepared at the observatory. This instrument will be made of steel, and is designed principally for fundamental work.

The old prime vertical transit instrument of 4·86 inches aperture and 77 inches focus was similar to that in the Pulkowa Observatory, but before remounting it in the new prime vertical building it was entirely remodelled. The telescope is now perfectly symmetrical, and consequently the observing slit in the roof and sides of the building is single, not of the usual double form. All the manipulations of the level are effected by suitable mechanism worked from the back of the northern pier, and the reading is effected from the same point by means of a small telescope. Thus the entire operation of levelling the instrument is executed by the observer without moving from his position behind the northern pier, and without touching either the level or the light which illuminates it. The reversal of the instrument is done by pointing the telescope to the zenith and then turning a handle on the southern pier, first in one direction until the instrument is lifted from its Ys and reversed, and then in the opposite direction until it comes down upon the Ys in its new position; the time occupied by the whole operation being from 15 to 20 seconds.

All the instruments and apparatus employed in testing chronometers at various temperatures, and in distributing time signals to the public, are located in the office building. A

40-feet horizontal photoheliograph, which has been used in observing various transits of *Venus* and *Mercury*, is mounted in connection with the photographic building; and a complete set of magnetic instruments of the Kew pattern, both absolute and self-registering, is mounted in the magnetic building and its underground vault. W. H.

The Observatory on Mont Blanc.

In 1891 it was decided to found a wooden structure in the snow on the summit of Mont Blanc, as experiments made by M. Eiffel had shown that it was not found practicable to reach the rock. In the last Report a description was given of the building which had been completed at Meudon and was ready for transportation. By the end of 1892 the building was dismounted and transferred by successive stages to Chamounix, to the Grand Rocher Rouge, and to the Grands-Mulets. In 1893 the materials were conveyed to the top of the mountain by means of a series of windlasses, and by September 8 the observatory was built, the partitions, floors, and staircase completed, and only one part of the verandah remained unfinished. On September 11 Dr. Janssen reached the summit, and inspected the building, which met his approval for the most part, but he was dissatisfied with the depth to which the base of the building had been sunk. To secure complete stability a greater proportion should have been buried. He then carried out a series of observations on the B group of the solar spectrum, the results of which would lead us to suppose that at the limits of our atmosphere the entire group would disappear, and that this and the other great oxygen groups in the solar spectrum are of purely earthly origin. The instruments employed included a Rowland grating spectroscope, with telescopes of 0·75 focal length, showing all the details of the B group. A. S. D. R.

The Reflecting Zenith Telescope.

Georgetown College Observatory has already brought the photochronograph into practical use with the transit instrument, and a memoir recently issued from the same institution describes a new application of its principle. The device of the reflecting zenith telescope is due to Father José Algué, S.J., a student of this college, and is an extension of a hint of Professor Küstner that the micrometer of an ordinary zenith telescope might be replaced by a photographic camera. The instrument much resembles in appearance an ordinary transit tube, but the eyepiece is omitted and an objective substituted,

provided with adjusting screws and similar to the object-glass at the other end. Their apertures are 5 cm., and they have each a focal length of 64 cm. to ensure the trailing of 7th magnitude stars. In the common focal plane is placed a plate-holder consisting of a thin glass plate. The sensitive plate has its film in contact with one of the faces of this, so that both the direct and the reflected rays of the stars must pass through a thin glass layer before acting on the sensitive film. On the glass holder are engraved two perpendicular lines called respectively the *vertical* and *horizontal* lines. The mercury reflecting surface is preferably stationed as far as possible from the instrument to admit of the observation of stars as near the zenith as possible, and to prevent disturbance of the surface by the tube. The photochronograph is essentially the same as that used in the floating telescope. Sectors are cut out of two aluminium discs and are rotated by an anchor armature engaging a toothed wheel on their axis. By a spring contact each make or break of the circuit advances the toothed wheel half a tooth, and the spokes are thus swept across the field in front of the two faces of the sensitive film, alternately transmitting to it or cutting off from it the light of a passing star. The great disadvantage of the instrument is the exclusion of those pairs of stars very near the zenith. This can be more or less obviated by removing the mercury trough to as great a distance as possible from the objective. Though the reflected trails are not as sharp and regular as the direct trails, this is scarcely to be counted a disadvantage, as it affords a means of identifying the trails. The flexure error of the tube due to the action of gravity is a more serious matter, but can be eliminated if a pair is observed on successive nights by alternately photographing each star by the direct and reflected methods. The advantages of this form are—1st, the transits of the two stars may be simultaneous, as each has its own objective, and thus errors due to instrumental or meteorological changes may be reduced to a minimum; 2nd, the instrument is not touched between the observations of the two stars; and 3rd, pairs of stars whose difference of zenith distance is much greater than usual can be observed, as the reflection from the mercury renders one part of the sky symmetrical with the other, and only so much of the screw is needed as corresponds to half the difference of zenith distance. A. S. D. R.

The Universal Time Movement.

During the past year some progress has been made with the project for adopting a zonal system of time on the Continent of Europe, similar to the system which has been in use for some years past in America. On April 1 Germany adopted mid-European time, one hour fast on Greenwich, as the legal standard time for the

Empire. On November 1 the same system was adopted in Italy, and from the first day of the current year mid-European time has been in use in Denmark. A law also has been passed in Switzerland authorising the use of this time throughout the country from June 1 next. A Bill, with a similar object, was introduced in the Austrian Reichsrath, but there is at present no information as to its having been passed.

The following table gives the present position of affairs.

Country.	Standard Time.
England, Belgium, Holland	Greenwich Time.
Denmark, Germany, Italy, Switzerland*, Norway and Sweden†	1 hour fast on Greenwich Time.
Japan	9 hours fast on Greenwich Time.
Australia‡	9 hours fast on Greenwich Time.
United States and Canada	4, 5, 6, 7, or 8 hours slow on Greenwich Time, according to longitude.

At the time when the standard time was changed in Italy, the 24-hour system of reckoning was also introduced, 0 hours being midnight.

The Weather.

Dependent as astronomers necessarily are on atmospheric circumstances for the successful prosecution of their labours, the Council have not usually included in their report information on the meteorological conditions of the year; but the weather of 1893 was in various aspects of a character so remarkable, especially as regards the amount of clear sky, that the astronomer, equally with the meteorologist, may be interested in having some particulars thereof placed on record. At the Royal Observatory, Greenwich, the amount of cloud is estimated on a scale of 0–10 (0 = cloudless, 10 = overcast), and four observations are usually taken daily at the hours of 9, 12, 15, and 21 of civil time. In all months of the year 1893, excepting January and November, the mean amount of cloud (mean of the four observations) was below the average of the previous seventy-five years, and in some months remarkably so. The mean for March was 4·0, and for April 3·1, the least previous values for these months since 1818 having been 5·0 in 1841 and 3·7 in 1840 respectively, both in excess of the values for 1893. The means for June, August, October, and December, were also small, that for December

* From 1894 June 1.

† It is believed that the standard time in these countries differs by a few seconds from mid-European.

‡ Proposed at the Postal and Telegraph Conference, 1894.

being 5·9, there having been since 1818 only one other less value, 5·7 in 1822. That two months in succession, March and April, should both have such exceptionally small values shows the persistency of the clear weather in the spring. The mean for the whole year was 5·7, which is the smallest yearly value since 1818. The results for March and April are corroborated by the sunshine records, the number of hours of sunshine in both months having been considerably above the average for the years during which such records have been taken. The period was thus unusually favourable for continuous scrutiny of solar changes, but many astronomers will be more interested in learning some particulars of the state of the evening sky. The number of days in each month that the sky was cloudless at 21^h (9^h ordinary astronomical reckoning) was—in January, 6; February, 9; March, 20; April, 18; May, 8; June, 10; July, 6; August, 13; September, 13; October, 12; November, 6; and December, 12. Altogether an unusual record, especially for March and April. Air temperature was high in 1893, being on twenty-nine days above 80° (highest, 95°·1); only in four years since 1841 has there occurred a greater number of days with temperature above 80°. In the months from March to June rain was very deficient, 1·9 inches only having been recorded as against an average of 7·1 inches. W. E.

PAPERS READ BEFORE THE SOCIETY FROM MARCH 1893 TO JANUARY 1894.

1893.

Mar. 10. Observations of *Saturn* in 1892. J. Guillaume.

Physical observations of *Mars*, made at the Allegheny Observatory in 1892. J. E. Keeler.

On certain variable Stars having the appearance, visually, of planetary nebulæ. C. E. Peek.

Observations of *Mars* and ι *Aquarii* near their conjunction on 1892 November 4. John Tebbutt.

Historical note on the parallel plate double-image micrometer. J. H. Poynting.

Observations of the position-angle of the ring of *Saturn*. A. Stanley Williams.

On the orbit of Σ 1728. J. E. Gore.

On the orbit of β 416. J. E. Gore.

Photograph of the nebula M. 77 *Ceti*. Isaac Roberts.

Photograph of the cluster M. 103 *Cassiopeiæ*. Isaac Roberts.

Photographs of Holmes' Comet (*f* 1892). Isaac Roberts.

Observations of Brooks' Comet (*g* 1892) and Holmes' Comet (*f* 1892), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

A micrometer for measuring the plates of the Astrophotographic Chart. W. H. M. Christie.

Apr. 14. Results of double star measures with the 8-inch Equatorial at Windsor, New South Wales, in 1892. John Tebbutt.

Photograph of the cluster M. 34 *Persei*. Isaac Roberts.

Photograph of the nebula Ih II. 240 *Pegasi*. Isaac Roberts.

Comparison of the Greenwich Ten-Year Catalogue (1880) with the Cape Catalogue (1880). H. H. Turner and H. P. Hollis.

Revised places of Comets observed at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Telescopic Objectives for photographic purposes. H. Dennis Taylor.

1893.

Apr. 14. Observations of Comets, made at the Liverpool Observatory, 1892–93. W. E. Plummer.

Galactic longitudes and latitudes of the brighter stars in a zone of the heavens containing the Milky Way. A. Marth.

On the parallactic inequality of the Earth's motion around the Sun. E. J. Stone.

Observations of the recent conjunction of *Saturn* and *γ Virginis*, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the orbit of OΣ 285. J. E. Gore.

May 12. The orbit of *τ Cygni* (A. G. C. 13). S. W. Burnham.

Photograph of the cluster M. 35 *Geminorum*. Isaac Roberts.

Photograph of the cluster M. 36 *Aurigæ*. Isaac Roberts.

Photograph of the cluster M. 37 *Aurigæ*. Isaac Roberts.

Photograph of the cluster M. 50 *Monocerotis*. Isaac Roberts.

Immersions and emersions of *Jupiter's* Satellite IV. Rev. S. J. Johnson.

Negatives of *Jupiter* made with the great telescope of the Lick Observatory during the opposition of 1892–93. Professors E. S. Holden, W. W. Campbell, and A. L. Colton.

Note on the determination of the Moon's mass. E. J. Stone.

Ephemeris for physical observations of *Jupiter*, 1893–94. A. Marth.

Observations of the planets *Mars* and *Ceres*, made at the Royal Observatory, Greenwich, about the time of their recent conjunction. Communicated by the Astronomer Royal.

June 9. The motion of Σ 1819. S. W. Burnham.

The orbit of 40 *Eridani* = Σ 518. S. W. Burnham.

Observations of the satellites of *Saturn* in 1893. Rev. A. Freeman.

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Ephemeris of the fifth satellite of *Jupiter*, 1893. A. Marth.

Expression of the radius vector of the Moon's orbit as disturbed by the Sun to the fifth order of small quantities. E. J. Stone.

Nov. 10. The orbit of *Sirius*. S. W. Burnham.

Probable errors of Greenwich observations of close circumpolar stars. T. Lewis.

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1893.

Nov. 10. Results of micrometer comparisons of *Saturn* and γ^1 *Virginis*. John Tebbutt.

Tables to facilitate the application of Gauss' method of computing secular variations. R. T. A. Innes.

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On the reduction of measures of photographic plates. H. H. Turner.

Observations of phenomena of *Jupiter's* satellites, made at Windsor, New South Wales, in the year 1892. John Tebbutt.

Photograph of the nebula ♅ I. 168 *Ursæ Majoris*. Isaac Roberts.

Photograph of the nebula ♅ I. 205 *Ursæ Majoris*. Isaac Roberts.

Method of finding the latitudes of *Saturn's* belts. Rev. A. Freeman.

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Observations of Brooks' Comet (*c* 1893), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

The secondary colour aberrations of the refracting telescope in relation to vision. H. Dennis Taylor.

Observations of Comet Rordame-Quénisset (*b* 1893), made at the Liverpool Observatory. W. E. Plummer.

Observations of the Moon, made at the Radcliffe Observatory, Oxford, during the year 1892, and a comparison of the results with the tabular places from Hansen's *Lunar Tables*. E. J. Stone.

Dec. 8. On the rotation of *Saturn*. A. S. Williams.

Observations of double stars, made at the Sydney Observatory. Communicated by H. C. Russell.

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The periodic variation in the motion of 61 *Cygni*. H. Jacoby.

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To adjust the polar axis of an equatorial telescope for photographic purposes. Dr. A. A. Rambaut.

Observations of the variable stars W and X *Sagittarii*. Lieutenant-Colonel E. E. Markwick.

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Note on a Star-Correction Facilitator, or an instrument for readily obtaining the products of pairs of numbers, one number being taken from one set (*e.g.* day-constants), and the second from another set (*e.g.* star-constants). T. C. Hudson.

On errors that may arise in estimating star magnitudes by photography. Captain W. de W. Abney.

1894.
Jan. 12. On the dark poles and bright equatorial belt of the first satellite of *Jupiter*. E. E. Barnard.

Photograph of the nebulæ ♄I. 56 and 57 *Leonis*. Isaac Roberts.

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Ephemerides of the five inner satellites of *Saturn*, 1894. A. Marth.

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Note on the transit of *Mercury* over the Sun's disc, which takes place for *Venus* on March 21, 1894; and on the transits of *Venus* and *Mercury* which occur for *Saturn's* system on the same day. A. Marth.

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ADDRESS

Delivered by the President, Captain W. de W. Abney, C.B., R.E., D.C.L., F.R.S., on presenting the Gold Medal to Professor S. W. Burnham.

THE Gold Medal of the Royal Astronomical Society has been awarded by the Council to Mr. S. W. Burnham for his discovery and measurement of double stars; and following the custom of the Society, it is the duty of the President to lay before it the grounds on which the award has been made.

I can scarcely hope to do justice to the labours entailed in the extensive researches made by Mr. Burnham, and to his discoveries. I believe I am correct in stating that Mr. Burnham's first astronomical communication was made to the *English Mechanic*. It is, however, with his star catalogues and other later communications to which your attention must be drawn. The catalogues of double stars which he has given us amount to no fewer than nineteen containing 1,274 new double stars.

Burnham's first catalogue of new double stars, published in 1873, consisted of 81 pairs, which were discovered with a 6-inch Alvan Clark refractor at Chicago, and occupied his time from 1870 to 1872. The distances of the doubles in this, as in several of his first catalogues, were estimations and not exact measurements, his telescope not being furnished with a micrometer. It may here be incidentally remarked that during the discovery of some of these pairs he was in communication with Dembowski, who measured many of them, whilst others were measured by our Fellow, Mr. Knott, and appear in his catalogue. The measures by Dembowski were not published till after this observer's death, and were, comparatively speaking, recently (1888) printed by the Reale Accademia dei Lincei at Rome. The first catalogue contains several pairs which are very difficult to see with a 6-inch, even when they are known to be doubles. For instance—

Number in Catalogue.	Magnitudes.	Distances.
		"
4	7 and 7½	0·5
13	8 „ 12	1·0
63	6 „ 12	0·7

Burnham's second catalogue contained twenty-five new double stars, and was like the first published by this Society in its *Monthly Notices* and in the same year, viz., 1873. The 6-inch was still his instrument, and the class of star is about the same, as will be seen from the following examples:—

Number in Catalogue.	Magnitudes.	Distances.
89	9 and 9	0″·6
96	6 „ 14	2·5
104	7 „ 12	2·5

His third catalogue contained seventy-six new doubles, and was also published in 1873. In this Burnham began to impose restrictions on his observations, rejecting distances exceeding 5″ and faint pairs below the ninth magnitude when not connected with a brighter star. He thus early appears to have grasped the true idea of weeding out, instead of cataloguing, useless or uninteresting pairs. The four following stars are from this catalogue:—

Number in Catalogue.	Magnitudes.	Distances.
120 ν Scorpii	4 and 8	0″·3
138	$7\frac{1}{2}$ „ 10	1·0
141	$7\frac{1}{2}$ „ $8\frac{1}{2}$	0·4
151 β Delphini	$3\frac{1}{2}$ „ 5	0·7

This catalogue is important, as containing a class of double star peculiar to Burnham's catalogues. I refer to pairs where the principal star is a naked-eye star, and the companion close and faint.

In the pair ν *Scorpii*, the principal star is one of the 4th magnitude and the companion of the 8th magnitude, at a distance of less than half a second. The discovery of this pair is a remarkable feat with a 6-inch, and the more so as another companion to ν *Scorpii* had been measured by many observers before, and the chief component must have been well scrutinised. Burnham says, "I examined it several times under the most favourable circumstances, but could not get rid of an apparent elongation of the principal star in a direction nearly north and south. I requested Professor C. A. Young to examine it with the splendid 9·4-inch Clark refractor of the Dartmouth College Observatory. He examined it several times, and at last when the air was very steady he was rather inclined to think it double, although he could not even notch it." This star was early known as a wide pair, and Jacob at Madras in 1847 found the companion was also double. The close pair was in 1874 measured with the 26-inch Washington refractor, and by Dembowski.

From what has been said, it must be evident that Burnham

has a remarkable acuteness of vision, and an eye wonderfully free from defects, such as astigmatism, which would render observations such as these impracticable.

The fourth catalogue was published in the *Monthly Notices*, June 1874. The fifth catalogue has 71 more new pairs, and brings out a peculiar characteristic of your medallist. If a star disc deviated an almost infinitesimal quantity from the circular, his eye detected it at once. In 1874, at Washington, on the night of August 11, he scanned some of his old discoveries, with the result that he made an addition of 14 new pairs to his list. I give one instance. No. 291 in the catalogue had on some occasion offended his critical eye when looking at it through the 6-inch, so he turned the 26-inch on it and found it consisted of two 8½-magnitude stars separated by a distance of only 0·2″. Turning, by chance, the telescope on to 34 *Pegasi* its mystery also disappeared, for a faint companion 2″ south was discovered.

In 1870, when your medallist began his work, very little was being done in discovering new doubles. Most observers were contented with the catalogues of the Struves and Herschel, and, so far as I can gather, he had no intention to add largely to these catalogues. His acute eye, however, rendered it impossible for him to stop. His small, though very perfect, instrument was the means of breaking through that resolution, if he had formed one. As already mentioned, Mr. Burnham has added a new class of double stars—viz. naked-eye stars with faint companions. The more difficult of these were discovered with the 36-inch Lick refractor, and have already become interesting. Out of the 1,274 new double stars which he has discovered, 197 are naked-eye stars, not previously known to be double. Of the 1,274 no fewer than 120 have been proved to be physically connected by later measures. He has found new components to 113 old pairs, as follows:—

W. Struve (Mensuræ Micrometricæ)	47
O. Struve (Pulkowa Catalogue)	14
W. Herschel	14
J. Herschel	22
South	9
South and Herschel	7

When Mr. Burnham had the use of the 15½-inch refractor of the Dearborn Observatory, his catalogue still showed that the maximum dividing power was what he sought, and a star from his eleventh catalogue will exemplify this. In this catalogue was *β Scorpii* of the second magnitude, with a companion of the tenth magnitude, distant only 0·8″. Even *he* considered it a very difficult pair, and, up to that time, far beyond any close pair discovered, in the inequality of its components. No second-class instrument, however large, would show its duplicity.

In the same catalogue are

	Magnitudes.	Distances.
η Cygni	4·5 and 13	7″·2
52 Hydræ	5·0 ,, 11	4·0
54 Herculis	5 ,, 12·5	2·6

When the great 36-inch telescope was placed at his command, hé determined to still further restrict the class of star to be measured, and in selecting stars for his working catalogue, he gave the preference to such as could not or would not be observed elsewhere, leaving the easier systems to others. Speaking generally, I am informed that the most difficult to observe are the most interesting; and but for the care he bestowed on the most difficult of the old systems, as well as those of his own discovery, a serious gap would have occurred in the measures.

An idea of the recent catalogues may be derived from an analysis of his eighteenth, which contains the numbers β 1225 to β 1266, that is, 42 pairs.

	Distances.	Pairs.	
Under	1″	15	
Between	1 and 2	13	42
,,	2 ,, 3	7	
Above	3	7	

As specimens may be cited

Numbers.	Distances.	Magnitudes.
1226	0″·40	8·5 and 10·5
1240	0·15	5·6 ,, 6·0
1241	0 53	5·9 ,, 10·0

The faintness of the companions and the small distances of the recent Burnham pairs indicate interesting researches for the possessor of the most powerful telescopes.

In all, your medallist, as before said, has published nineteen catalogues, containing 1,274 pairs, and I believe I am correct in saying that still one more catalogue is in the press, for I learn that the proof sheets of some 250 pages have left his hands for publication. These, it may be presumed, contain the complete catalogue of all the stars which your medallist has discovered.

Of the 1,274 stars already published,

123 pairs	are	under	0″·5	apart
230 ,,		between	0·5 and 1	,,
370 ,,		,,	1 ,, 2	,,
168 ,,		,,	2 ,, 3	,,
178 ,,		,,	3 ,, 6	,,
205 ,,		over	6	,,

Thus, of all known pairs whose distance is under 1″, Mr. Burnham has added more than one half.

We must also note that, besides the measures of his new stars, we are indebted to him for many thousands of measures of previously known doubles.

Not only is Mr. Burnham an original observer, but he is a critic as well. He criticised the catalogue of Sir J. Herschel in a paper in the *Monthly Notices* in 1873.

Nor did the Bedford Catalogue escape his searching scrutiny. A paper in 1880 June in the *Monthly Notices* dealt with it somewhat severely. But all his criticisms have had the object of correcting and pointing out errors. His paper on the Trapezium of *Orion* is an example of this. He shows that the minute stars which were said to lie within it and to be visible with small telescopes are, to say the least, mythical. It has only been with the 36-inch Lick telescope that any minute stars have been found, and these would be invisible in any telescope less than a 30-inch.

Not less excellent work has been carried out by your medallist in calculating the orbits of binaries; and, as an example of the original way in which he sets to work, one has only to refer to his paper in the *Monthly Notices* of April 1891 on the Orbit of the Companion of *Sirius*. It may be mentioned that he was the last to obtain measures of the companion of *Sirius* in 1890. In 1891 he failed to detect it with the 36-inch Lick telescope. With these last observations before him, he recomputed the orbit, and found a period for it shorter than those of Gore or Howard, his period being 53 years, whilst theirs were 58·47 and 57·02 respectively. Should this orbit be correct, the companion should be again visible this year.

Of double stars discovered by Burnham which have short periods, the following are some of the most remarkable :—

	Period.	Period determined by
κ Pegasi β 989	11·37	Burnham
β 883	16·35	Glasenapp
85 Pegasi = β 733	17·48	,,
β Delphini = β 151	22·97	,,
9 Argûs = β 101	23·3	Burnham
β 416	24·7	,,
20 Persei = β 524	27·7	,,
β 612	30·0	Glasenapp

It appears that there are only two other binaries whose known periods are less than 25 years. I may interpolate here a word as to a second most valuable paper on inviaible double stars, in the same number of the *Monthly Notices* in which his paper on *Sirius* appears, as it indicates well his critical capabilities. In it he treats of the irregularities in the measures of certain

double stars. These irregularities have been ascribed to the presence of a dark body in the system, and in some suggestive diagrams Mr. Burnham indicates his opinions on the subject.

It may here be noted that Burnham, in his astronomical career, has used a variety of telescopes—the 6-inch his first, a 9·4-inch at Dartmouth, the 12-inch Lick, the 15½-inch Washburn, the 18½-inch Chicago, the 26-inch Washington, the 36-inch Lick. With him, increase of aperture available meant a further refinement in his researches, and a further power for interesting work.

The catalogues of the double stars and of orbits calculated by Burnham are a formidable work to have been accomplished by any one man; but when it is remembered that this is the more serious phase of his labours, and does not include much of what one might almost characterise as a lighter character which he has contributed to astronomy, it seems almost impossible to realise that it lay within the capacity of any one individual. The *English Mechanic*, the *Monthly Notices and Memoirs of the R.A.S.*, the *Astronomische Nachrichten*, the *American Journal of Science*, *Astronomy and Astro-Physics*, *Knowledge*, the *Sidereal Messenger*, the *Observatory*, and various other papers have been enriched by his contributions. The line of work that he laid himself out to accomplish he has successfully carried through. It is not of that showy or dramatic order which attracts universal attention, or gives occasion for newspaper paragraphs. It is, however, as arduous as it is unpretending; and when more than twenty years have been devoted to it, and when the success which has attended it has been so remarkable, it does honour to the Society to recognise the high estimation in which it holds this work by awarding to its author the greatest distinction it can confer.

Mr. Burnham is an amateur in the true sense of the word. Born about 1840, as far as I can learn, he adopted the vocation of stenographer, and it was not till he had chosen his profession that his mind was fortunately directed to the study of astronomy. What his first toy telescope may have been I know not; but from the time when he secured his 6-inch Clark, he made the progress in the direction that he had determined to follow. By day he followed his regular calling, whilst by night he studied the heavens till (as an article in *The Century* informs us) "daylight drove him to bed." In 1874 he became a Fellow of this Society, being nominated by his friend the late Rev. T. W. Webb, an astronomer to whose well-known book, apparently, Burnham was indebted for the turn which his astronomical labours were to take. In 1876 Burnham was appointed Director of the Chicago Observatory, a post which he held for a short time, though he subsequently had the use of the 18½-inch telescope at that observatory. In 1879, when the trustees of the Lick Observatory had chosen Mount Hamilton as the site on which to build their observatory, he was selected, on the recommendation of Professor Newcomb, to report on the

atmospheric and other conditions of that locality, and subsequently observed the Transit of *Mercury* from the same spot in conjunction with Professor Holden. This connection with Mount Hamilton was not destined to cease, for he was appointed to a post in the Lick Observatory, where he turned the magnificent telescope of that institution to good account in his researches. Lately he retired from the position occupied there and resumed his work at Chicago, and now holds the appointment of Professor of Practical Astronomy at that university. It is to be hoped that he will be only temporarily absent from an established observatory; for, if rumour is to be believed, he is to be Astronomer to the Yerkes Observatory, where the great 40-inch telescope is to be erected. If this be so, the choice made by the trustees is an honour to him and to themselves.

I think, gentlemen, I have said enough to convince you that the medal has been worthily bestowed and well earned, and in handing it to our honoured foreign secretary, Dr. Huggins, to transmit to him, I would ask him at the same time to convey a message from the Royal Astronomical Society "in Annual Meeting assembled," wishing Mr. Burnham health and strength to continue his contributions to astronomical science, and expressing their gratitude to him for what he has done for it in the past.

The meeting then proceeded to the election of the Officer and Council for the ensuing year, when the following Fellows were elected:—

President.

Captain W. de W. Abney, C.B., R.E., D.C.L., F.R.S.

Vice-Presidents.

A. M. W. Downing, Esq., M.A., D.Sc., Superintendent of the "Nautical Almanac."
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.
E. B. Knobel, Esq.
E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

Treasurer.

A. A. Common, Esq., LL.D., F.R.S.

Secretaries.

E. W. Maunder, Esq.
H. H. Turner, Esq., M.A., B.Sc., Savilian Professor of Astronomy, Oxford.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

Council.

W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
Frank McClean, Esq., M.A.
W. H. Maw, Esq.
H. F. Newall, Esq., M.A.
Captain William Noble.
A. Cowper Ranyard, Esq., M.A.
Isaac Roberts, Esq., D.Sc., F.R.S.
G. M. Seabroke, Esq.
Rev. Walter Sidgreaves, S.J.
E. J. Spitta, Esq.
G. Johnstone Stoney, Esq., M.A., F.R.S.
Lieut.-Gen. J. F. Tennant, C.I.E., R.E., F.R.S.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. MARCH 9, 1894. No. 5

Captain W. de W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

Augustin Stanislaus Ghosh, 28 Convent Road, Calcutta;
Lieutenant William H. F. Montanaro, R.N., H.M.S. *Canada*, Bermuda;
Walter A. Post, Newport News, Virginia, U.S.A.;
Alexander William Roberts, Lovedale, Alice, Cape Colony,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers, from personal knowledge, being appended:—

John Briggs, B.A. Cantab., University Tutorial College, Red Lion Square, W.C. (proposed by Dr. R. Bryant);
Rev. Samuel Robert Browne, M.A., LL.D., Mathematical Master in Bristol Grammar School, Camelot, St. John's Road, Clifton (proposed by F. H. Stevens);
Rev. F. J. Eld, M.A. Oxon., Whiteladies, Worcester (proposed by Captain W. de W. Abney);
Henry Owen, F.R.G.S., F.R.Met.Soc., Royal Thames Yacht Club, 7 Albemarle Street, W. (proposed by Capt. R. Reynolds);
George C. Pulsford, Head Master, Royal Hospital School, Greenwich, S.E. (proposed by H. H. Turner);
W. Rickmer Rickmers, Schwarzspanierstrasse, Vienna (proposed by Herbert Ingall);
William Stewart Stewart, Levern House, Barrhead, Scotland (proposed by Adam Hilger).

One hundred and three presents were announced as having been received since the last meeting, including, amongst others:—

Annals of the Astronomical Observatory of Harvard College, vols. xxv., xxix., xxxi. part 2; vol. xl. part 2, presented by the Observatory; A. Auwers, Tobias Mayer's Sternverzeichniss, nach den Beobachtungen auf der Göttinger Sternwarte, 1756-60, presented by Professor Auwers; H. Gyldén, Traité Analytique des orbites absolues des huit planètes principales, tome i., presented by the author; photographs of portions of the Moon, retouched enlargements from negatives taken at the Lick Observatory, presented by Dr. L. Weinek.

Remarks upon Mr. Stone's Proposed Corrections to the Measure of Time since 1864. By Professor Simon Newcomb.

In the December number of the *Monthly Notices* Mr. Stone presents a very able and elaborate statement of certain corrections which he claims should be applied to the adopted measure of time from and after the beginning of 1864, together with the resulting corrections to the tabular places of the Moon derived from Hansen's tables. The great importance of the question raised by Mr. Stone seems to make it only respectful to him that I should once more state the difficulty in the way of accepting his conclusions.

The following numbers are extracted from Mr. Stone's paper on page 4 of the *Monthly Notices* for November, which give the results of certain Radcliffe observations of the Moon, made in 1892:—

Date, 1892 *January* 6.

	m s
Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864	41·51
Observed Right Ascension of the Moon	49 19·57
R.A. from Hansen's Tables for uncorrected Mean Times ...	20·93
Hansen minus observed uncorrected	+1·36
Correction due to the change of unit in M.T.	−1·46
Hansen minus observed corrected	−0 10

In this and other papers it is claimed by Mr. Stone that the above correction of $41^{s}\cdot51$ to the sidereal time of mean noon since 1864 has resulted from a progressive change, starting from the epoch 1864·0 and increasing uniformly at the rate of about $1^{s}\cdot48$ annually. From this it follows that the tabular Right Ascensions of the Moon at transit over the meridian at Oxford, as computed from Hansen's Tables, should on the above date

receive a correction of $1^s \cdot 36$ in consequence of the alleged change in the sidereal time at mean noon.

The claim that this correction starts from zero about 1864·0, and increases uniformly at the rate of about $1^s \cdot 48$ annually, is based by Mr. Stone on the fact that that was the date when Le Verrier's tables were introduced into the *Nautical Almanac*, and when, in consequence, according to Mr. Stone's theory, the new measure of time began.

Now, to show my difficulty, let us suppose that the old tables of the Sun had been continued up to the end of the year 1891, and that in the year 1892 Le Verrier's Tables had for the first time been introduced. To make my meaning perfectly clear I shall call the case of actual introduction in 1864, case A; and the supposed case of introduction in the year 1892, case B. On Mr. Stone's theory, the time t should in case B be counted from 1892·0, and the correction therefore for 1892 January 6 would have been substantially zero.

But it is evident that the tabular numbers for the whole year 1892, and therefore for January 6, would have been exactly the same in case B as they are in case A; that is to say, if the solar ephemeris from Le Verrier's Tables had been computed for the first time for the year 1892, all the quantities taken from the tables and printed in the *Nautical Almanac* would have been the same as they actually are. To claim that they would have been different would imply that the results of making a computation from Le Verrier's Tables are not merely a function of the numbers contained in the tables, but of the time when they began to be used for the ephemeris of the *Nautical Almanac*. Were this doctrine true it might also be possible that the quantities taken out from a table of logarithms were different from year to year. As this cannot be the case it conclusively follows that all the numbers used in computing the tabular place of the Moon at transit over the meridian of Oxford on 1892 January 6 would be exactly the same in case B that they are in case A. Consequently the result would have been the same as Mr. Stone gives it for the uncorrected time; that is to say, we should have had—

	m	s
Observed Right Ascension of the Moon	49	19·57
R.A. from Hansen Tables for uncorrected M.T.		20·93
Hansen minus observed uncorrected		+1·36
Correction due to the change of unit in M.T.		0·00
Hansen minus observed corrected		+1·36

Thus Mr. Stone's theory and his method of applying it give a correction zero for 1894·0 in case B, when in fact the numbers to be corrected are the same as they are in case A. From this conclusion I see no escape. From Mr. Stone's theory the use of the new unit of time would, in case B, have commenced in 1894.

Here t must be reckoned from 1894·0, and the correction must be zero. Thus his theory gives two inconsistent corrections to the same numbers.

Note on Professor Newcomb's Remarks. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

Professor Newcomb's attempt to disprove my views by a *reductio ad absurdum* will be found to rest upon an interesting example of the very common logical fallacy of a *petitio principii*.

I have proved, or at least profess to have proved, in the *Monthly Notices*, vol. liv., that, with the two independent systems of time-measurement adopted in practical astronomical work, the tabular right ascensions, α^s, for the transits over an observer's meridian at the time $r+\delta r$ can only be accurately found from the equation

$$(1)\qquad \alpha^s = \phi\,(r+\delta r) = \phi\,(r) + \frac{d}{dt}\,\phi\,(r)\left[\frac{\alpha^s - A_r^{s\prime} - \delta l^s - 86400^s \cdot x r}{24^h\left(1+\frac{N}{2\pi}+x\right)}\right] + \&c.,$$

where $\phi(r)$ is the tabular right ascension computed directly from the tables for the time $t=r$; $A_r^{s\prime}$ the "local sidereal time at mean noon," computed for the time $t=r$, from a set of solar tables adopted for this purpose, and also used to fix the time at which in each year the Sun's mean longitude is equal to 280°; the corrections δl^s and x are quantities whose magnitudes depend upon the differences between the constants l and N, adopted for the epoch constant and mean motion of the Sun per "unit day" in the formation of the solar tables employed, and certain definite constants l_0 and N_0, which, if they had been adopted instead of l and N, would have rendered the corrections δl^s and x zero. These corrections, δl^s and x, necessarily change with the adoption of different values of l and N in our solar tables.

Now Professor Newcomb, undoubtedly following the usual course, determines certain quantities α_1^s from the equation

$$(2)\qquad \alpha_1^s = \phi\,(r) + \frac{d}{dt}\,\phi\,(r)\left[\frac{\alpha_1^s - A_r^{s\prime}}{24^h\left(1+\frac{N}{2\pi}\right)}\right] + \&c.,$$

and calls the results thus obtained the tabular right ascensions at the meridian transits.

But if the equation (1) is exact, the equation (2) is inexact, and *vice versâ*.

It is therefore simply begging the question to assume, without proof, that the values of α_1^s found from the equation (2) are the correct tabular right ascensions at the meridian transits, and not the values α^s found from the equation (1).

If Professor Newcomb can *prove* that with the dual systems of time-measurement in use in practical astronomical work the equation (1) is inexact and (2) is exact, then there is an end of my explanation of the cause of the change of the residual differences (Tabular R.A. from Hansen—Observed R.A. of Moon) about the year 1864, which is evident when the quantities a_s' computed from the equation (2) are adopted as the tabular right ascensions for the meridian transits. But, on the other hand, if my proofs of the equation (1) are sound, the explanation of this *per saltum* change is shown conclusively to result from the differences between the quantities $a^s - a_s'$ before and after 1864, which directly result from the different values of the constants l and N employed in the formation of the solar tables in use before and after 1864.

The discussion of the residuals (Hansen—Observed) is not appealed to as a proof of the truth of the equation (1), which must be, and has been, independently proved; but it is certainly no disproof to show that if we neglect the corrections $\delta l^s + 86400^s \cdot xr$ and use the quantities a_s' for the tabular right ascensions at the meridian transits of the Moon, the residuals which should remain sensibly unchanged about 1864, if the neglect of these corrections is a legitimate one, are found to have changed to such an extent that the same mean motions will not represent the observations before and after that date, and that these *per saltum* changes disappear when the tabular right ascensions are computed from equation (1).

Tables to Facilitate the Application of Gauss's Method of Computing Secular Variations. By R. T. A. Innes.

In Vol. I. of Newcomb's Astronomical Papers of the American Ephemeris, Professor G. W. Hill suggested the computations of the functions $\chi(\tau)$ and $\psi(\tau)$, both functions of θ.

If we take another function α related to θ as follows:—

$$\frac{1-\alpha}{1+\alpha} = \sqrt{-\frac{\cos\left(60^\circ + \frac{\theta}{3}\right)}{\cos\frac{\theta}{3}}}.$$

M. O. Callandreau has published tables to six places of $\log m^4 n^4 \chi(\tau)$ and $\log \frac{\psi(\tau)}{\chi(\tau)}$ in vol. xviii of *Les Annales de l'Observatoire de Paris* for 580 values of α from $-0{\cdot}000$ to $1{\cdot}000$, its extreme limits.

I had, previously to seeing M. Callandreau's tables, com-

menced calculating log M and log N, using θ as the argument. They are connected with Hill's functions as follows:—

$$M = \left[\frac{\cos\left(60° - \frac{\theta}{3}\right)}{\cos\theta} \right]^{-2} \psi(\tau)$$

$$N = \frac{\psi\tau}{\chi\tau}.$$

I believe such tables of log M and log N will be useful to astronomers as a check to M. Callandreau's. They also avoid the calculation of the intermediate function a.

Most of the values of log M and log N given in the tables herewith were computed with seven-figure logarithms, so that the last figure is uncertain. I have arranged the tables in the form—

$$f(\theta + h) = f(\theta) + h\frac{df}{d\theta} + h^2\frac{1}{2}\frac{d^2f}{d\theta^2}.$$

Thus to compute log N for $-52° 32' 36''$, which we may write $-52° - °\cdot5433$ or $-53° + °\cdot4567$

$-52°$	gives	+0·1381654		$-53°$	gives	+0·1385790
$-\cdot5433$	,,	+ 2278		$+\cdot4567$	,,	− 1864
$+\cdot295$	,,	− 16		$+\cdot21$	,,	− 11
		+0·1383916				+0·1383915

The differences from 60° to 90° of θ are not given; they will be required but rarely, and M. Callandreau's tables are to be preferred for high values.

The numerical application of Hill's formulæ suggests a few modifications.

We may divide A, B, and C by a^2; the value of θ will be unchanged. V may be equal to

$$p + q\frac{\psi(\tau)}{\chi(\tau)}.$$

Then q may be removed from F_1, F_2, and F_3.

In F_1 and J_1 write $\left(\frac{a'}{a}\right)^2$ or a^2 for $\frac{1}{a^2}$, a being the disturbing planet. From F_3, J_3, and $\frac{a}{\tau}W_0$ the factor sin I may be removed to the final equations. From $\frac{a}{\tau}R_0$, $\frac{a}{\tau}S_0$, and $\frac{a}{\tau}W_0$ the factor

$$\left(\frac{a_1}{a}\right)^2 \cos^2\phi$$

may be likewise removed to the end.

We have now

$$\frac{a}{r}R_0 = \left(\frac{r}{a}\right)q^{-\frac{7}{2}}\left[\frac{\cos\left(60^\circ - \frac{\theta}{3}\right)}{\cos\theta}\right]^{-7} M(F_1 + J_1 V)$$

with corresponding equations for $\frac{a}{r}S_0$ and $\frac{a}{r}W_0$.

Not the least merit of Gauss's methods consists in its numerous checks. Besides the even and odd functions agreeing in the totals, as pointed out by Professor Hill, we get from

$$\left[\frac{da}{dt}\right] = 0$$

the valuable check

$$B_0^{(c)} = -\frac{1}{2}A_1^{(s)}\chi\tan\phi.$$

Also as A, B sin ϵ, B cos ϵ, J_1, &c., can be made explicit functions of sin E, cos E, &c., the sum total of values can be ascertained at the beginning, and will prevent systematic errors. One example will suffice :—

$$B\sin\epsilon = -\left[k_1\frac{a_1}{a}e\cos\phi_1\sin K_1\right] + C_1\cos E + C_2\sin E_1;$$

and as the sums of cosines and sines for any even regular division of the circumference is nil, if we take n divisions, the sum total of B sin ϵ will be

$$-n\left[k_1\frac{a_1}{a}e\cos\phi_1\sin K_1\right].$$

Gauss's method will also give the perturbations independent of the position of the disturbing planet. In the case of the Earth disturbed by *Venus* we have approximately

$$\frac{d\phi}{dt} = \frac{m_1 n}{1+m}\left(\frac{a_1}{a}\right)^2\cos^2\phi_1\cos\phi\sin E\,.\,\frac{a}{r}R_0;$$

$$\int\frac{d\phi}{dt}dt = \frac{-m}{1+m}\left(\frac{a_1}{a}\right)^2\sin 1''\,A_3^{(c)}\sin(l''-\varpi'');$$

$$\delta\phi = 0''\cdot 908\sin(l''-\varpi''). \qquad [\text{Le Verrier} = 0''\cdot 907.]$$

θ	Log M	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$	Log N	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$
−90°	9·5573194	− 0	− 38	0·1461280	− 0	−55
−89	9·5573156	− 77	− 38	0·1461225	− 110	−55
−88	9·5573041	− 153	− 38	0·1461060	− 220	−55
−87	9·5572849	− 230	− 38	0·1460784	− 331	−55
−86	9·5572581	− 306	− 38	0·1460398	− 441	−55
−85	9·5572237	− 383	− 38	0·1459902	− 551	−55
−84	9·5571816	− 460	− 38	0·1459296	− 662	−55
−83	9·5571318	− 536	− 38	0·1458579	− 772	−55
−82	9·5570743	− 613	− 38	0·1457752	− 882	−55
−81	9·5570092	− 690	− 38	0·1456815	− 992	−55
−80	9·5569363	− 767	− 38	0·1455768	− 1102	−55
−79	9·5568559	− 843	− 38	0·1454610	− 1213	−55
−78	9·5567677	− 920	− 39	0·1453342	− 1323	−55
−77	9·5566718	− 997	− 39	0·1451964	− 1433	−55
−76	9·5565682	− 1074	− 39	0·1450476	− 1544	−55
−75	9·5564569	− 1152	− 39	0·1448877	− 1654	−55
−74	9·5563378	− 1229	− 39	0·1447168	− 1764	−55
−73	9·5562111	− 1306	− 39	0·1445348	− 1875	−55
−72	9·5560766	− 1384	− 39	0·1443419	− 1985	−55
−71	9·5559343	− 1461	− 39	0·1441379	− 2095	−55
−70	9·5557843	− 1539	− 39	0·1439228	− 2205	−55
−69	9·5556265	− 1617	− 39	0·1436968	− 2316	−55
−68	9·5554609	− 1695	− 39	0·1434597	− 2426	−55
−67	9·5552875	− 1773	− 39	0·1432116	− 2536	−55
−66	9·5551063	− 1851	− 39	0·1429524	− 2647	−55
−65	9·5549173	− 1929	− 39	0·1426822	− 2757	−55
−64	9·5547204	− 2008	− 39	0·1424010	− 2867	−55
−63	9·5545157	− 2087	− 39	0·1421087	− 2978	−55
−62	9·5543031	− 2165	− 39	0·1418054	− 3088	−55
−61	9·5540826	− 2244	− 40	0·1414911	− 3199	−55
−60	9·5538542	− 2324	− 40	0·1411657	− 3309	−55
−59	9·5536179	− 2403	− 40	0·1408293	− 3419	−55
−58	9·5533736	− 2483	− 40	0·1404818	− 3530	−55
−57	9·553121	− 2562	− 40	0·1401233	− 3640	−55
−56	9·5528612	− 2642	− 40	0·1397538	− 3750	−55
−55	9·5525929	− 2722	− 40	0·1393733	− 3861	−55
−54	9·5523167	− 2803	− 40	0·1389817	− 3971	−55
−53	9·5520324	− 2883	− 40	0·1385790	− 4082	−55

θ	Log M	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$	Log N	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$
°						
−52	9·5517400	− 2964	− 40	0·1381654	− 4192	−55
−51	9·5514395	− 3045	− 40	0·1377407	− 4302	−55
−50	9·5511309	− 3127	− 41	0·1373049	− 4413	−55
−49	9·5508141	− 3208	− 41	0·1368582	− 4523	−55
−48	9·5504892	− 3290	− 41	0·1364004	− 4633	−55
−47	9·5501561	− 3372	− 41	0·1359315	− 4744	−55
−46	9·5498147	− 3455	− 41	0·1354517	− 4854	−55
−45	9·5494651	− 3537	− 41	0·1349608	− 4964	−55
−44	9·5491072	− 3620	− 42	0·1344588	− 5074	−55
−43	9·5487410	− 3703	− 42	0·1339459	− 5184	−55
−42	9·5483665	− 3787	− 42	0·1334220	− 5295	−55
−41	9·5479834	− 3871	− 42	0·1328870	− 5405	−55
−40	9·5475922	− 3956	− 42	0·1323410	− 5515	−55
−39	9·5471924	− 4040	− 42	0·1317840	− 5625	−55
−38	9·5467841	− 4125	− 42	0·1312160	− 5735	−55
−37	9·5463674	− 4210	− 43	0·1306369	− 5845	−55
−36	9·5459420	− 4296	− 43	0·1300469	− 5955	−55
−35	9·5455081	− 4382	− 43	0·1294459	− 6065	−55
−34	9·5450656	− 4468	− 43	0·1288339	− 6175	−55
−33	9·5446144	− 4555	− 44	0·1282109	− 6284	−55
−32	9·5441545	− 4643	− 44	0·1275770	− 6394	−55
−31	9·5436858	− 4730	− 44	0·1269321	− 6504	−55
−30	9·5432084	− 4818	− 44	0·1262762	− 6614	−55
−29	9·5427221	− 4907	− 44	0·1256093	− 6723	−55
−28	9·5422270	− 4996	− 44	0·1249316	− 6832	−55
−27	9·5417229	− 5085	− 45	0·1242429	− 6941	−55
−26	9·5412099	− 5175	− 45	0·1235433	− 7051	−55
−25	9·5406879	− 5266	− 45	0·1228327	− 7160	−55
−24	9·5401568	− 5356	− 46	0·1221113	− 7269	−54
−23	9·5396166	− 5448	− 46	0·1213790	− 7378	−54
−22	9·5390673	− 5540	− 46	0·1206357	− 7487	−54
−21	9·5385087	− 5632	− 46	0·1198817	− 7595	−54
−20	9·5379409	− 5725	− 46	0·1191167	− 7704	−54
−19	9·5373638	− 5818	− 47	0·1183410	− 7812	−54
−18	9·5367773	− 5912	− 47	0·1175544	− 7920	−54
−17	9·5361814	− 6007	− 47	0·1167571	− 8027	−54
−16	9·5355760	− 6102	− 48	0·1159490	− 8135	−54
−15	9·5349610	− 6197	− 48	0·1151301	− 8243	−54

θ	Log M	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$	Log N	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$
°						
−14	9·5343364	− 6293	− 48	0·1143005	− 8350	−54
−13	9·5337022	− 6390	− 49	0·1134601	− 8457	−54
−12	9·5330583	− 6488	− 49	0·1126091	− 8564	−53
−11	9·5324045	− 6586	− 49	0·1117474	− 8670	−53
−10	9·5317410	− 6686	− 50	0·1108751	− 8776	−53
− 9	9·5310674	− 6785	− 50	0·1099922	− 8882	−53
− 8	9·5303839	− 6885	− 51	0·1090987	− 8988	−53
− 7	9·5296902	− 6986	− 51	0·1081946	− 9093	−52
− 6	9·5289865	− 7088	− 51	0·1072800	− 9198	−52
− 5	9·5282726	− 7191	− 52	0·1063549	− 9303	−52
− 4	9·5275483	− 7294	− 52	0·1054195	− 9407	−52
− 3	9·5268137	− 7399	− 52	0·1044736	− 9510	−52
− 2	9·5260686	− 7504	− 53	0·1035174	− 9614	−52
− 1	9·5253130	− 7609	− 53	0·1025508	− 9717	−52
0	9·5245468	− 7716	− 53	0·1015739	− 9820	−51
+ 1	9·5237699	− 7823	− 54	0·1005869	− 9922	−51
+ 2	9·5229823	− 7932	− 54	0·0995895	−10024	−51
+ 3	9·5221837	− 8040	− 55	0·0985821	−10124	−50
− 4	9·5213742	− 8151	− 55	0·0975647	−10224	−50
+ 5	9·5205536	− 8262	− 56	0·0965374	−10324	−50
+ 6	9·5197219	− 8373	− 56	0·0954999	−10424	−50
+ 7	9·5188789	− 8487	− 57	0·0944526	−10522	−49
+ 8	9·5180245	− 8601	− 57	0·0933955	−10620	−49
+ 9	9·5171588	− 8715	− 58	0·0923286	−10717	−48
+10	9·5162815	− 8831	− 58	0·0912521	−10813	−48
+11	9·5153925	− 8949	− 59	0·0901659	−10909	−48
+12	9·5144917	− 9067	− 59	0·0890704	−11004	−47
+13	9·5135791	− 9186	− 60	0·0879652	−11098	−47
+14	9·5126545	− 9307	− 61	0·0868508	−11190	−46
+15	9·5117177	− 9429	− 61	0·0857271	−11283	−46
+16	9·5107687	− 9552	− 62	0·0845942	−11374	−45
+17	9·5098073	− 9676	− 62	0·0834523	−11464	−45
+18	9·5088334	− 9802	− 63	0·0823014	−11553	−44
+19	9·5078469	− 9929	− 64	0·0811418	−11640	−44
+20	9·5068476	−10057	− 64	0·0799734	−11727	−43
+21	9·5058355	−10186	− 65	0·0787964	−11813	−43
+22	9·5048104	−10318	− 66	0·0776110	−11896	−42
+23	9·5037720	−10450	− 66	0·0764173	−11979	−41

θ	Log M	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$	Log N	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$
+24°	9·5027204	−10584	− 67	0·0752152	−12060	−40
+25	9·5016552	−10720	− 68	0·0740053	−12139	−39
+26	9·5005764	−10857	− 69	0·0727875	−12217	−39
+27	9·4994838	−10996	− 70	0·0715619	−12293	−38
+28	9·4983773	−11136	− 71	0·0703288	−12368	−37
+29	9·4972565	−11279	− 71	0·0690884	−12441	−36
+30	9·4961215	−11422	− 72	0·0678407	−12511	−35
+31	9·4949721	−11568	− 73	0·0665861	−12580	−34
+32	9·4938080	−11716	− 74	0·0653247	−12647	−33
+33	9·4926290	−11865	− 75	0·0640567	−12711	−32
+34	9·4914349	−12016	− 76	0·0627825	−12773	−30
+35	9·4902257	−12170	− 77	0·0615022	−12833	−29
+36	9·4890009	−12327	− 78	0·0602160	−12889	−28
+37	9·4877604	−12484	− 79	0·0589243	−12944	−27
+38	9·4865041	−12643	− 80	0·0576272	−12996	−25
+39	9·4852317	−12806	− 82	0·0563251	−13044	−24
+40	9·4839429	−12970	− 83	0·0550183	−13090	−22
+41	9·4826377	−13137	− 84	0·0537070	−13133	−20
+42	9·4813155	−13307	− 86	0·0523918	−13171	−19
+43	9·4799762	−13479	− 87	0·0510728	−13208	−17
+44	9·4786196	−13654	− 88	0·0497504	−13239	−15
+45	9·4772454	−13832	− 90	0·0484251	−13266	−13
+46	9·4758533	−14012	− 91	0·0470972	−13290	−11
+47	9·4744430	−14196	− 92	0·0457671	−13309	− 9
+48	9·4730142	−14382	− 94	0·0444354	−13324	− 6
+49	9·4715666	−14572	− 96	0·0431023	−13334	− 4
+50	9·4700998	−14765	− 97	0·0417686	−13338	− 1
+51	9·4686136	−14961	− 99	0·0404348	−13339	+ 2
+52	9·4671077	−15160	−101	0·0391009	−13332	+ 4
+53	9·4655815	−15365	−103	0·0377683	−13319	+ 7
+54	9·4640347	−15572	−105	0·0364371	−13302	+11
+55	9·4624671	−15783	−107	0·0351078	−13278	+14
+56	9·4608781	−15998	−109	0·0337816	−13246	+18
+57	9·4592675	−16217	−111	0·0324587	−13208	+21
+58	9·4576346	−16442	−113	0·0311401	−13162	+25
+59	9·4559793	−16669	−116	0·0298263	−13107	+30
+60	9·4553008	−16904	−118	0·0285187	−13043	+34

θ	Log M	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$	Log N	$\frac{d}{d\theta}$	$\frac{1}{2}\frac{d^2}{d\theta^2}$
+61°	9·4525986	...	...	0·0272177		
+62	9·4508724	...	...	0·0259244		
+63	9·4491215	...	...	0·0246398		
+64	9·4473455	...	...	0·0233648		
+65	9·4455436	...	...	0·0221007		
+66	9·4437154	...	...	0·0208485		
+67	9·4418600	...	...	0·0196097		
+68	9·4399769	...	...	0·0182853		
+69	9·4380653	...	...	0·0171772		
+70	9·4361245	...	...	0·0159863		
+71	9·4341535	...	...	0·0148149		
+72	9·4321517	...	...	0·0136632		
+73	9·4301180	...	...	0·0125364		
+74	9·4280515	...	...	0·0114334		
+75	9·4259511	...	...	0·0103575		
+76	9·4238157	...	...	0·0093111		
+77	9·4216442	+	...	0·0082976		
+78	9·4194350	...	...	0·0073169		
+79	9·4171869	...	...	0·0063752		
+80	9·4148983	...	...	0·0054748		
+81	9·4125674	...	...	0·0046197		
+82	9·4101922	...	...	0·0038142		
+83	9·4077706	...	...	0·0030629		
+84	9·4053004	...	...	0·0023717		
+85	9·4027783	...	...	0·0017468		
+86	9·4002011	...	...	0·0011964		
+87	9·3975647	...	...	0·0007299		
+88	9·3948632	...	...	0·0003601		
+89	9·3920884	...	...	0·0001062		
+90	9·3892283	...	...	0·0000000		

Sydney: 1893 *June* 19.

On the Rotation of Saturn. By A. Stanley Williams.

Introductory.

The rotation of *Saturn* was discovered in 1793 by Herschel from observations of variations in the appearance of his well-known quintuple belt in the southern hemisphere of the planet. Herschel concluded that the rotation was performed in a period of $10^h\ 16^m\ 0^s{\cdot}4$ of mean time, and that this period "must be exact to much less than two minutes either way." * The observations extend over a period of 154 rotations.

An interval of no less than eighty-three years then occurred without any further addition being made to our knowledge of this important quantity. At length, in 1876 December, a bright spot was detected by Professor Asaph Hall, with the Washington 26-inch refractor, near the planet's equator. This spot was two or three seconds in diameter, round, and well defined, and of a brilliant white colour. From a careful discussion of the observations of this spot by six different observers, Professor Hall determined the period of rotation to be $10^h\ 14^m\ 23^s{\cdot}8 \pm 2^s{\cdot}30$.†

In the spring of 1891 a number of bright spots were detected by the writer in the bright equatorial zone of *Saturn*, south of the planet's equator. The observations of these spots have not yet been completely discussed; but, according to Mr. Marth, the motion of five spots (four bright and one dark), of which the observations have been published,‡ is approximately represented by a period of $10^h\ 14^m\ 21^s{\cdot}84$.§

A great many observations of these bright equatorial spots were obtained during the opposition of 1892. The spots themselves were also seen by two or three other observers. These observations have not yet been discussed, but they are probably represented approximately by the rotation period of $10^h\ 13^m\ 38^s{\cdot}4$ adopted by Mr. Marth in his Ephemeris for 1893.‖

The foregoing is a summary of our knowledge respecting the rotation of *Saturn* up to the present year. The remainder of this paper is devoted to a discussion of the results obtained during the opposition of 1893. Most of the observations were made by the writer, but satisfactory results were also obtained by six additional observers, besides several others who saw the spots, but have not given sufficient particulars to enable them to be identified.

* *Philosophical Transactions*, 1794, p. 66.

† *Ast. Nach.*, No. 2146. During the observations sixty-one rotations were performed by the planet.

‡ *Ast. Nach.*, No. 3051.

§ *Monthly Notices*, vol. li. p. 568. Mr. Denning from the observations of ten bright equatorial spots, but employing only the extreme observations of each spot and an approximate method of reduction, makes the rotation period $10^h\ 14^m\ 26^s{\cdot}6$ (see *Observatory*, 1891, p. 369).

‖ *Monthly Notices*, vol. liii. p. 153.

Methods of Observation.

The observations here given, excepting those attributed to other observers, were all made with a 6½-inch reflector by Calver, a power of 225 being generally used, and occasionally 320 when the weather permitted. Three principal methods were employed to determine the positions of spots, namely—

1. *Direct transits.*—In these the time at which a spot seemed to be in mid-transit, or bisected by the central meridian of the disc, was recorded as exactly as possible. This is the method usually employed in the case of the planet *Jupiter*, and it is capable of giving very satisfactory results with this planet in the hands of a careful observer. But with *Saturn* it is not enough to rely wholly upon these direct transits. The spots of *Saturn* are generally so delicate that on an average night it not unfrequently happens that, owing to an interval of unsteady definition, it may not be practicable to see them distinctly for sometimes ten minutes or even more at a time. And the occurrence of such a period of poor seeing at the critical time results in many a direct transit being lost. In order to make up for such losses, and to further increase the accuracy with which the times of the passages over the central meridian of the disc may be fixed, I have therefore largely had recourse to the following:—

2. *Estimated transits.*—An observer systematically devoting himself to the observation of the spots of *Saturn* or of *Jupiter* soon becomes acquainted with the rate at which such spots appear to move across the disc through the rotation of the planet. If, then, a spot be seen at a short distance preceding or following the central meridian of the disc, it is easy for such an observer to estimate the time of the actual transit; and that, too, with considerable accuracy, provided that the object observed is not distant much more than twenty minutes from the transit, either way. Such an estimation forms what is here called an *estimated transit*, an illustration of which will be given later on. This method has one great advantage when observations of such delicate objects as the spots on *Saturn* are in question; and that is, that it is not necessary to wait for some definite moment, which may be lost owing to an interval of poor definition, but at any instant that a clear view of a spot is obtained an estimated transit may be made.

3. A third method consists in recording the time when a spot transits, not over the central meridian of the disc, but over some other meridian, such as the meridian distant thirty degrees from the central meridian. This method is not, however, susceptible of great exactness, and it was only employed in a few exceptional cases.

A direct transit and at least three or four estimated transits of a spot were made on each night whenever the circumstances permitted of so doing. The mean of such estimated transits has

been considered to be of the same value as a direct transit, and the simple mean of the two adopted as the concluded time of transit of the spot. The following example, extracted from my observation book, will serve to illustrate this :—

1893 March 21, $12^h\ 25^m$ (clock time): Dark northern spot β transited. Two e S, m D, pretty well-defined spots on the two chief belts in the northern hemisphere. These two form the most conspicuous and definite dark spots which I have ever seen on these belts. They are quite plain and easy. Estimated transits as under:—

h	m	m	h	m	
12	9 +	12 =	12	21.	225, seen plainly.
12	16 +	7 =	12	23	,, well seen.
12	36 −	17 =	12	19	,,
12	44 −	23 =	12	21	,, definition very confused.

Mean of estimated transits	= 12	21
Direct transit	= 12	25
Mean	= 12	23
Clock correction	=	−3·5
Concluded time of transit	= 12	19·5 G.M.T.

The first of the above estimated transits signifies that at $12^h\ 9^m$ the spot was estimated to be 12^m before transit; the last, that at $12^h\ 44^m$ it was 23^m past transit.

Great pains were taken to avoid any possibility of bias from recollection of previous observations. The experience of preceding years had shown that this is most important, and that errors amounting to as much as a quarter of an hour in the time of a transit may sometimes be made if the observer has some preconceived idea, perhaps erroneous, of the time when a spot ought to transit, from recollection of the work of some preceding night. Accordingly, in the present series of observations, great efforts were made to avoid all recollection of previous results. The times were just recorded in the observation-book, and then intentionally forgotten. This succeeded so well that the whole of the observations of 1893 are absolutely independent, and unaffected by any possibility of bias. This, however, it should be remarked, applies only to the results of different nights; as when a number of estimated transits of a spot were made upon the same night it was impossible sometimes in the later transits to avoid all recollection of the earlier ones, however hard one might try.

Determination of the Period of Rotation.

Great care was also taken in the final reduction of the observations to ensure that the results were free from any possibility of their being influenced by preconceived ideas. Whilst the work of observation was in progress, all reference to the re-

corded observations was purposely avoided, and it was not until the month of June that the reductions were commenced. The whole of the observations were then reduced, and the concluded times of transit determined in the manner indicated above before any attempt was made at comparing them. The observations were also weighted in as uniform a manner as possible; that is to say, they were weighted partly according to the degree of satisfaction given by them at the time of observation and partly according to the number of observations. All the weights were also finally fixed before any attempt was made at comparison of the different observations, and they have not in any case been subsequently altered, with the single exception that an observation of spot *o* has been reduced from weight 1 to weight $\frac{1}{2}$. A weight $\frac{1}{2}$ signifies that the observations are very rough or few in number. In no case has the concluded time of transit of a spot been subsequently altered. The observations having all been uniformly reduced in this manner, the corresponding longitudes were calculated from Mr. Marth's Ephemeris, and the results laid down upon a diagram or chart (Plate 5) in which the horizontal lines represent dates, and the vertical lines longitudes; the black dots represent the writer's observations, those of other observers being represented by circles. The connection between the different observations could then be readily seen, and lines were drawn through the observations of the same spots.

The method adopted in order to determine the period of rotation from these observations is as follows. In his 'Ephemerides of the Five Inner Satellites of Saturn,' 1893,* Mr. Marth has given a list of the times when an adopted zero meridian would pass the middle of the illuminated disc of *Saturn*. These times are based upon a period of rotation of $10^h\ 13^m{\cdot}64$, and they have already received the necessary corrections for the varying positions of the Earth and *Saturn*, for the light equation, and for phase. It is consequently an easy matter to determine the corrections to be applied to the above period from the observations. Thus, if t be the observed interval in time by which a spot follows the assumed zero meridian at one observation, and t' the corresponding interval at another observation, then the difference between t and t' divided by the number of rotations of the planet in the interval between the two observations will give the correction to be applied to the rotation period of the Ephemeris ($10^h\ 13^m{\cdot}64$). An example will make this clear. Spot β followed the zero meridian of the Ephemeris on March 21 by an interval of $0^h\ 58^m{\cdot}1$. On May 25 this interval was $3^h\ 10^m{\cdot}4$. The difference between the two amounts to $132^m{\cdot}3$. In the interval between these two observations the planet completed 152 rotations; so that we have $\frac{132{\cdot}3}{152}=0^m{\cdot}870$ as the correction to be applied to the period of the Ephemeris from the comparison

* *Monthly Notices*, vol. liii. p. 153.

SATURN - Spot Chart for 1893.
4 Feb.
1 Mar.
5 Apr.
5 May
4 June
Feb. 4
Mar. 1
Apr. 5
May 5
σ
π
ν
μ
τ
κ
θ
η
ε
δ
γ
β
α
ρ

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between these two observations, which correction will be additive.

The operation here performed has been repeated, so that each observation has been compared with all the other observations of the same spot, and the simple mean of the comparisons of one observation with all the others has been considered as the period of rotation given by such observation, and to have a corresponding weight; and the weighted mean of all the different results is the concluded period of rotation of the spot.

The nature of the tables which follow will now be readily comprehended. The first four columns explain themselves. Column five contains the observed times of transit reduced to some specified epoch by means of the concluded period of rotation, and column six the differences from the mean of such reduced observations. In the seventh column will be found the rotation periods resulting from the comparison of each observation with all the others.* The following abbreviations are used in the descriptive notes: S=small, v S=very small, e S=exceedingly small, B=bright, m B=moderately bright, F=faint, v F=very faint, D=dark, v=very, m=moderately.

Two kinds of spots were observed in 1893, namely: (1) Dark spots upon a conspicuous double belt in the northern hemisphere; and (2) bright spots in the equatorial zone. It will be advisable to consider each of these separately.

The Dark Spots in the Northern Hemisphere.

These were somewhat numerous, and consisted of small dark spots upon a prominent double belt in the northern hemisphere. According to my observations the spots were nearly invariably double, or arranged in pairs, one on each of the two bands of the double belt, the component spots of each pair lying nearly north and south with respect to each other. On favourable nights the spots were seen double in this manner very distinctly, some of the plainer ones being in fact quite dark and definite. But with poor definition it was often difficult to see the spots distinctly double, the appearance being then that of one larger and more diffuse spot extending over the whole width of the double belt. Both M. Quénisset at Juvisy and M. Rudaux at Donville have, however, figured single spots situated upon only one band of the belt, the companion spots on the other band not having apparently been seen. One of the spots was also observed by Mr. A. Henderson at Liverpool, so that altogether they were seen by four different observers. The darkest and best defined of these spots were, in fact, comparatively easy to observe, and the accordance of the observations is, on the whole, very satis-

* With the exception of those cases where the interval between the two observations is very short, such as 2–6 days; since in such short intervals the unavoidable accidental errors of the observations have an enormously disproportionate effect upon the result.

factory. The Rev. A. Freeman also noted once that when the double N belt was best seen "its bands were mottled." A similar appearance seems to have been seen by some other observers.

Dark Spot α.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 16.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
May 7	10 11·5	66·8	2	9 16·7	−0·2	10 14 27·1	(*a*)
13	9 32·0	72·5	3	13·8	−3·1	31·9	(*b*)
16	9 14·1	76·3	4	14·1	−2·8	33 8	(*c*)
June 8	10 29·0	109·9	½	9 23 0	+6·1	10 14 40·1	(*d*)

Description.—(*a*) v S, v F, v delicate. (*b*) 2 e S, F spots, v delicate. (*c*) 2 v S, F spots, well seen. (*d*) Glimpsed.

The mean period of rotation is $10^h\ 14^m\ 32{\cdot}1^s \pm 1^s{\cdot}22$, the number of rotations completed by the planet between the extreme observations being 75.

Dark Spot β.

Date.	G.M.T. of Transit	Long.	Weight.	Obs. reduced to April 14.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 21	12 19·5	34·1	4	9 49·1	− 2·8	10 14 32·8	(*a*)
Apr. 5	(10 35)	(45·8)	...	(38·7)	(−13·2)	...	(*b*)
14	9 53·0	64·9	3	53·0	+ 1·1	31·5	(*c*)
May 4	11 15·0	89·6	1	54·4	+ 2·5	29·8	(*d*)
22	9 22·4	110·5	3	53·4	+ 1·5	30·7	(*e*)
25	9 0·1	111·7	3	9 49·5	− 2·4	10 14 27·8	(*f*)

Description. (*a*) 2 e S, m D spots. (*b*) Obs. by Henderson. (*c*) 2 e S spots. South spot F, N. one v F; projecting S. of belt. (*d*) v S, F, not seen dup. (*e*) 2 e S, m D spots, seen v distinctly. (*f*) 2 e S, m D spots.

The simple mean of the rotation periods in col. 7 is $10^h\ 14^m\ 30^s{\cdot}5 \pm 0^s{\cdot}57$ (152 rotations). This spot, or actually pair of spots, was unusually definite, so that it could be well observed. The observations consequently agree very satisfactorily. In fact the accordance is really remarkable, as will be seen from the residuals in the 6th column. The observation of April 5 was made by Mr. Arthur Henderson at Liverpool with a 10½-in. reflector, power 336. At $10^h\ 35^m$ "the N. dark belt appeared slightly darker on the meridian."*

* *English Mechanic*, April 28, 1893, p. 225.

Dark Spot γ.

Date.	G.M.T. of Transit.	Long.	Weight.
	h m	°	
Mar. 24	12 25·3	52·2	3 (*a*)
Apr. 20	9 51·4	93·0	4 (*b*)
26	9 4·7	94·6	1 (*c*)

Description.—(*a*) v S, m D, dup., plain. (*b*) 2 v S, m D spots. (*c*) Plain.

The observations are insufficient to give a reliable period of rotation. Comparing the first observation with the second and third, the resulting periods of rotation are respectively $10^h\ 14^m\ 44^s{\cdot}7$ and $10^h\ 14^m\ 34^s{\cdot}8$. Giving half-weight to the latter result, the period of the spot would be $10^h\ 14^m\ 41^s{\cdot}4$.

Dark Spot δ.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 10.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Apr. 29	9 26·1	121·7	2	11 43·1	−0·7	10 14 33·4	(*a*)
May 8	8 35·0	135·0	1	47·5	+3·7	30·9	(*b*)
10	11 46·3	136·9	1	46·3	+2·5	30·1	(*c*)
13	11 20·3	136·0	1	38·7	−5·1	36·7	(*d*)
22	10 30·0	150·1	2	44·4	+0·6	30·1	(*e*)
25	10 10·3	152·9	3	11 43·0	−0·8	10 14 27·8	(*f*)

Description.—(*a*) S, F, susp. dup. (*b*) v S, m D, probably dup., quite plain. (*c*) Probably F, but def. bad. (*d*) v S, v F, v delicate. (*e*) v S, F, probably dup. (*f*) v S, F, probably dup.

Mean period of rotation$=10^h\ 14^m\ 30^s{\cdot}8 \pm 0^s{\cdot}84$ (61 rotations). The accordance of the observations is very satisfactory.

Dark Spot ε.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 5.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 8	14 58·1	47·0	1	9 13·9	+2·3	10 14 26·8	(*a*)
May 5	9 11·9	142·2	3	11·9	+0·3	27·7	(*b*)
16	11 24·0	152·5	½	8·1	−3·5	29·3	(*c*)
June 9	8 59·7	182·2	1	9 12·7	+1·1	10 14 29·4	(*d*)

Description.—(*a*) Probably double. (*b*) v S (or S), m D, unusually plain. (*c*) S, F. (*d*) v S, v F, v delicate.

Giving to the observation of February 8 weight 3, because of the long interval separating it from the others, the mean period of rotation$=10^h\ 14^m\ 27^s{\cdot}7 \pm 0^s{\cdot}36$ (283 rotations). The observations, though not numerous, are again very accordant,

and as they extend over a long interval of time (121 days), the above period is a reliable one.

Dark Spot ζ.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 8.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Apr. 23	11 17·5	158·0	3	9 61·1	+1·9	10 14 55·4	(*a*)
May 8	9 56·7	182·9	1	56·7	−2·5	63·8	(*b*)
14	9 31·5	196·9	2	61·9	+2·7	63·0	(*c*)
26	8 26·5	216·2	1	9 57·3	−1·9	10 14 54·5	(*d*)

Description.—(*a*) v S, F, not seen clearly double. (*b*) v S, F. (*c*) 2 v S, F spots. (*d*) v S, F?

Mean period of rotation = $10^h\ 14^m\ 58^s{\cdot}6 \pm 1^s{\cdot}56$ (77 rotations). Observations again very accordant.

Dark Spot η.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to Apr. 21.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 31	10 13·0	128·6	4	8 29·0	−1·1	10 15 5·6	(*a*)
Apr. 21	8 32·0	171·2	½	32·0	+1·9	10 15 3·0	(*b*)
May 5	10 45·5	197·1	3	29·2	−0·9	10 15 1·2	(*c*)
17	(9 45·9)	(220·8)	...	(8 28·0)	(−2·1)	...	(*d*)

Description.—(*a*) 2 e S, m D spots, together quite plain. (*b*) No description, obs. v rough. (*c*) v S, F, well seen. (*d*) Obs. by Quénisset.

Mean period of rotation = $10^h\ 15^m\ 3{\cdot}7^s \pm 1^s{\cdot}01$ (82 rotations). The observations though few in number are very accordant. The last one is the result of measures of a sketch made by M. Quénisset at Juvisy with a 9·4-in. refractor,* and is in excellent agreement with my own observations. In this, as in all similar cases, the measures have been made and reduced prior to any comparison with other observations, so that there is no possibility of the resulting position having been affected by bias. M. Quénisset draws the spot on the northernmost of the two belts, and apparently did not notice the companion spot on the southernmost belt.

Dark Spot θ.

Date.	G.M.T. of Transit.	Long.	Weight.	
	h m	°		
Apr. 18	9 50·0	202·5	½	(*a*)
23	12 48·8	211·6	1	(*b*)
May 17	10 48·2	256·3	...	(*c*)

Description.—(*a*) S, D. (*b*) Apparently D, def. v confused. (*c*) Obs. by Quénisset.

* *L'Astronomie*, 1893, p. 327, fig. 124.

Observations insufficient to furnish a reliable period of rotation. Comparison of the two first observations makes it $10^h\ 14^m\ 56^s$, which agrees satisfactorily with the periods of the neighbouring spots. M. Quénisset's observation is based on measures of two sketches.* From one sketch the transit occurred at $10^h\ 55^m{\cdot}1$, and from the other at $10^h\ 41^m{\cdot}4$. The mean of these is the time given in the table, and it accords well with the other observations.

Dark Spot ι.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 11.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Apr. 24	9 33·5	221·9	1	11 28·5	−7·1	10 14 60·1	(*a*)
27	9 31·1	235·0	3	42·0	+6·4	43·3	(*b*)
May 11	11 35·2	255·1	2	35·2	−0·4	54·8	(*c*)
14	11 14·2	257·2	1	30·0	−5·6	52·4	(*d*)
June 7	9 21·5	305·5	3	11 42·4	+6·8	10 14 60·5	(*e*)

Description.—(*a*) v S, F. (*b*) S, F, nearly certainly dup. (*c*) v S, m D? (*d*) Probably v S, F. (*e*) v S, m D, well defined, probably dup.

Mean period of rotation $=10^h\ 14^m\ 53^s{\cdot}35 \pm 2^s{\cdot}40$ (103 rotations). The observations are not so accordant as in the case of the previous spots.

Dark Spot κ.

Date.	G.M.T. of Transit.	Long.	Weight.	
	h m	°		
Apr. 30	9 31·4	249·6	½	(*a*)
May 3	9 23·7	259·5	3	(*b*)
9	8 39·0	262·2	½	(*c*)

Description.—(*a*) v S, F. (*b*) 2 e S, F spots. (*c*) v S? m D?

Observations insufficient to give a reliable period of rotation.

Dark Spot λ.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to Apr. 30.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Apr. 18	11 38·5	266·2	1	10 34·1	+2·0	10 14 48·2	(*a*)
30	10 33·7	286·1	3	33·7	+1·6	41·5	(*b*)
May 6	9 53·8	291·6	2	25·9	−6·2	49·7	(*c*)
12	9 30·8	306·9	3	10 34·8	+2·7	10 14 65·9	(*d*)

Description.—(*a*) v S, F. (*b*) Dup. South spot v S, F; N. spot e S, F; projecting south of belt. (*c*) v S, F, probably dup. Time possibly 2^m in error. (*d*) 2 e S, F spots perhaps projecting south of belt.

* *L'Astronomie*, 1893, p. 327, figs. 124 and 125.

Mean period of rotation=$10^h\ 14^m\ 52^s{\cdot}2 \pm 3^s{\cdot}97$ (56 rotations). The observations are in good agreement. On two nights the spot projected south of the southernmost edge of the belt.

Dark Spot μ.

Date.	G.M.T. of Transit.	Long.	Weight.
	h m	°	
Apr. 27	11 6·0	290·6	1 (*a*)
May 18	9 16·7	327·4	1 (*b*)

Description.—(*a*) v S, F. (*b*) v S, v F, v delicate.

The period of rotation from these two observations is $10^h\ 14^m\ 55^s{\cdot}0$ (49 rotations), which agrees very closely with the periods of the neighbouring spots.

Dark Spot ν.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 3.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Apr. 19	9 15·7	307·2	1	11 30·4	−0·7	10 14 63·4	(*a*)
30	11 44·4	327·6	2	29·3	−1·8	59·2	(*b*)
May 3	11 36·5	337·4	3	36·5	+5·3	62·1	(*c*)
27	9 29·5	17·9	1	11 28·4	−2·7	10 14 57·2	(*d*)

Description.—(*a*) v S, v F, v delicate. (*b*) v S, F, rather ill defined. (*c*) v S, v F, probably dup. (*d*) v S, m D, well defined.

Mean period of rotation=$10^h\ 15^m\ 0^s{\cdot}9 \pm 0^s{\cdot}81$ (85 rotations). The observations are in very satisfactory accordance.

Dark Spot ο.

Date.	G.M.T. of Transit.	Long.	Weight.
	h m	°	
May 12	11 8·3	4·2	½ (*a*)
18	10 29·7	10·2	½ (*b*)

Description.—(*a*) v S, F. (*b*) Probably v S, glimpsed through cloud.

Observations insufficient to give the period of rotation with any exactness.

Dark Spot π.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 4.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 29	12 11·4	308·4	2	8 40·9	−4·0	10 14 43·6	(*a*)
May 4	8 43 3	0·6	1	43·3	−1·6	40·7	(*b*)
10	8 18·3	14·8	½	53·1	+8·2	38·0	(*c*)
June 2	9 20·5	41·2	2	8 42·3	−2·6	10 14 36·2	(*d*)

Description.—(*a*) v S, F, dup. (*b*) S, D, dup? plain. (*c*) Probably F, v rough obs. (*d*) v S, m D, well defined, probably dup, plain.

Mean period of rotation $= 10^h\ 14^m\ 40^s{\cdot}3 \pm 1^s{\cdot}27$ (152 rotations), the first observation having been given weight 3 on account of the long interval separating it from the others.

Dark Spot ρ.

Date.	G.M.T. of Transit.	Long.	Weight.
	h m	°	
May 1	9 34·0	16·0	3 (*a*)
June 8	9 17·0	67·6	4 (*b*)

Description.—(*a*) 2 e S, F spots, the N one slightly prec. the other. (*b*) 2 e S, m D, well defined spots, well seen.

Comparing these two observations together, the resulting period of rotation is $10^h\ 14^m\ 37^s{\cdot}8$ (89 rotations). As the observations both bear a high weight, and are separated by a considerable interval, this result is probably pretty exact.

Dark Spot σ.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 4.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 7	15 20 3	295·1	2	9 47·4	− 7·8	10 14 33·8	(*a*)
May 4	9 54·5	42·4	3	54·5	− 0·7	31·8	(*b*)
10	9 28·3	55·9	3	65·2	+ 10·0	27·1	(*c*)
June 2	10 21·5	77·0	1	9 53·7	− 1·5	10 14 27·0	(*d*)

Description.—(*a*) 2 e S, v F spots. (*b*) 2 e S, v F spots. (*c*) v S, F, probably dup. (*d*) v S, v F, v difficult.

Mean period of rotation $= 10^h\ 14^m\ 31^s{\cdot}1 \pm 1^s{\cdot}14$ (269 rotations), giving the first result weight 5 instead of 2 because of the long interval separating the observation from the others. The observations are not so accordant as usual, though, as they extend over a long interval of time, the period is a pretty reliable one.

Of the above spots, γ, θ, κ, μ, o and ρ may be dismissed from further consideration, since the observations of these spots are not sufficient to give the rotation periods with accuracy; although in every case, it should be observed, the observations of these spots accord excellently with those of neighbouring spots. There remain, then, eleven spots of which the periods of rotation are well ascertained, and these range themselves naturally into two classes or groups, according to the lengths of such periods, with one spot π nearly intermediate between the two groups. Thus we have:—

	Synonym.	Period of Rotation. h m s	s	No of Rotations.
Class A.	σ	10 14 31·1	±1·14	269
	α	10 14 32·1	±1·22	75
	β	10 14 30·5	±0·57	152
	δ	10 14 30·8	±0·84	61
	ϵ	10 14 27·7	±0·36	283
Class B.	ζ	10 14 58·6	±1·56	77
	η	10 15 3·7	±1·01	82
	ι	10 14 53·35	±2·40	103
	λ	10 14 52·2	±3·97	56
	ν	10 15 0·9	±0·81	89
	π	10 14 40·3	±1·27	152

Combining the different results, the following are the final values for the two groups :—

	h	m	s	s
Class A. Mean Period of Rotation ...	= 10	14	29·07	±0·27
Class B. „ „ „ ...	= 10	15	0·74	±0·56

there being rather more than half a minute ($31^s·67$) between the two.

The different results which compose each group agree closely *inter se*, the somewhat greater divergences in the case of Class B being due to the fact that the observations of the spots do not extend over such long intervals of time as do those of the spots forming Class A. It is clear, therefore, that the surface material rotated more than half a minute more quickly in the same latitude upon one side of *Saturn* than upon the other. Similar differences are common enough upon *Jupiter*, though even with this planet it is rare to find the difference so considerable and so well marked as in the present instance. Taking the date May 5 as a convenient epoch, the spots of Class A extend from longitude 45° to 140°, and those of Class B from longitude 175° to 340°, the intermediate region, exemplified by spot π, extending from about longitude 340° to 45°.

It will be well to explain here why there are so few observations in March and the early part of April, and why, in the case of closely adjacent spots, there are no instances of both spots having been observed upon the same night. The paucity of observations previous to the middle of April was due to poor definition, although otherwise the weather was remarkably favourable to observation, cloudy nights being, in fact, quite exceptional. The other peculiarity resulted from excess of caution. Not infrequently, after one spot had been observed, another one was seen close to it. But in such cases it was feared that the appearances might be deceptive, and the observations were either discontinued for an hour or two, in order to give

the eye a complete rest, or else confined for a time to the bright equatorial spots.

The Bright Equatorial Spots.

These were spots slightly brighter than the average surface of the bright equatorial zone, and resembling in appearance the bright spots which form such a characteristic feature of the corresponding region of *Jupiter*. Roughly circular in shape, they averaged about 2″ in diameter—perhaps a little less—but as they were usually very indefinite on the edges, it was generally difficult to distinguish a distinct boundary. Occasionally they were recorded as being very white, but more usually they appeared slightly yellowish in tint. Like the spots upon *Jupiter*, they seem to be variable in brightness.

Satisfactory observations of these spots were made in 1893 by four observers in addition to the writer, namely, Mr. H. MacEwen at Glasgow, Mr. G. L. Brown at Stirling, the Rev. P. H. Kempthorne at Wellington College, and M. Quénisset at Juvisy. Three or four other observers also saw the spots, but have not recorded times or positions.* Generally speaking, these bright spots were more indefinite than the dark spots previously treated of, and consequently the observations are not quite so accordant.

Bright Spot No. 1.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to Mar. 31.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 7	12 49·3	206·6	2	10 66·6	+ 7·6	10 12 56·6	(*a*)
Mar. 22	12 27·9	163·9	2	59·6	+ 0·6	57·7	(*b*)
31	10 59·5	155·9	1	59·5	+ 0·5	57·4	(*c*)
Apr. 23	10 30·1	130·2	1	50·8	− 8·2	61·4	(*d*)
29	9 28·8	123·3	3	48·1	−10·9	64·6	(*e*)
May 4	12 14·8	124·7	1	58·4	− 0·6	59·5	(*f*)
5	8 45·8	126·9	3	63·4	+ 4·4	55·0	(*g*)
13	10 50·2	118·3	3	61·1	+ 2·1	60·6	(*h*)
16	10 18·4	114·0	3	58·4	− 0·6	59·5	(*i*)
	(10 29·3)	(120·4)	...	(69·3)	(+10·3)	...	(*j*)
22	9 20·8	109·5	2	59·8	+ 0·8	61·0	(*k*)
25	8 44·8	102·7	1	52·7	− 6·3	56·3	(*l*)
June 8	10 9·0	98·1	½	66·4	+ 7·4	66·8	(*m*)
11	9 25·7	86·9	½	10 51·8	− 7·2	10 12 55·4	

Description.—(*a*) S, m B′, plain. (*b*) Probably m B. (*c*) v S, F. (*d*) No description, def. confused. (*e*) S, F, perhaps a double nucleated spot. (*f*) S, F. (*g*) S, m B, rather well defined, plain. (*h*) S, F, plain. (*i*) S, F, v white. (*j*) Obs. by Kempthorne. (*k*) v S, F. (*l*) S, m B, well defined, rich white colour, plain. (*m*) S, v F ?, v. rough obs.

* In 1892 the Rev. A. Freeman secured observations of several of these

Mean period of rotation = $10^h\ 12^m\ 59^s{\cdot}4 \pm 0^s{\cdot}61$ (291 rotations). The spot clearly did not move at a perfectly uniform rate. Thus between February 7 and April 29 its motion was a little swifter than that corresponding to the above period. Between the latter date and May 5 there occurred a rather sudden shift or displacement to the eastward, causing a difference of about 15^m in the time of the transit over the central meridian of the disc. Subsequent to May 5 the motion of rotation conformed closely to the adopted period of rotation of $10^h\ 12^m\ 59^s{\cdot}4$. The second observation of May 16 is the result of measures of a sketch made by the Rev. P. H. Kempthorne at Wellington College, with an 8½-inch reflector—power, 350. The last observation is derived from measures of a sketch published in *l'Astronomie*, 1893, p. 329, fig. 126.*

Bright Spot No. 2.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to May 4.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 10	13 8·0	128·8	2	10 63·1	+1·9	10 12 60·5	(*a*)
30	13 19·9	113·4	3	65·5	+4·3	60·4	(*b*)
Apr. 8	11 45	101·5	1	58·0	−3·2	63·4	(*c*)
9	8 8·9	99·6	½	55·9	−5·3	64·6	(*d*)
May 1	...	...	...	...	...	...	(*e*)
4	11 9·1	86·2	1	69·1	+7·9	59·1	(*f*)
7	10 24·8	74·6	3	53·8	−7·4	65·0	(*g*)
13	9 35·5	74·5	2	62·0	+0·8	59·0	(*h*)
16	9 7·1	72·2	4	62 4	+1·2	62 9	(*i*)
27	10 42·0	60·4	1	58·1	−3·1	58·4	(*j*)
June 2	9 50·5	58·8	1	10 63·9	+2·7	10 12 63·8	(*k*)

Description.—(*a*) v S, F or perhaps m B. (*b*) S, m B, seen brightly. (*c*) Obs. by MacEwen. (*d*) Obs. by Brown. (*e*) Seen, transit not obs. (*f*) S, m B, seen brightly. (*g*) S, F, v white. (*h*) S, F. (*i*) S, m B, well defined, quite plain and brilliant. (*j*) Probably v S, F, def. confused. (*k*) v S, v F, v difficult, definition poor.

Mean period of rotation = $10^h\ 13^m\ 1^s{\cdot}8 \pm 0^s{\cdot}49$ (197 rotations). The observation of April 8 was made by Mr. H. MacEwen at Glasgow, with a 5-inch refractor. The spot was observed in

bright equatorial spots. One of them was "easily seen" once by Professor Porro with the 11-in. refractor of the Turin Observatory. Mr. G. T. Davis, of Reading, even suspected one with only a 3¾-in. refractor. The Rev. W. R. Waugh frequently saw them at Portland with a 12½-in. reflector, both in 1892 and 1893.

* This sketch was made by M. Rudaux at Donville, but by a mistake it was attributed to Mr. Arthur Mee, and it is not clear at what time it was actually made. As, however, the calculations had been completed, and the adopted rotation period appears to satisfactorily represent all the other observations, no alteration has been made on this account.

mid-transit at the time given. The observation of April 9 was made by Mr. G. L. Brown at Stirling, with a 10¼-inch reflector. At 9h the spot was seen about 30° to the west of the central meridian. This spot was therefore observed by three different observers.

Bright Spot No. 3.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to April 20.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 16	12 33·4	137·9	2	10 13·1	−2·8	10 12 60·7	(*a*)
19	12 9·4	138·4	3	18·7	+2·8	56·1	(*b*)
31	10 9·1	126·3	4	16·8	+0·9	58·2	(*c*)
Apr. 20	10 15·7	107·2	2	15·7	−0·2	57·8	(*d*)
May 22	8 25·3	77·0	1	14·2	−1·7	58·3	(*e*)
June 8	9 8·7	62·8	3	10 16·7	+0·8	10 12 59·3	(*f*)

Description.—(*a*) v S, m B, well defined. (*b*) v S, m B. (*c*) S, m B, quite bright and easy. (*d*) v S, F, difficult. (*e*) S, m B, v white. (*f*) S, F, v white, plain.

Mean period of rotation=10h 12m 58s·3±0s·42 (197 rotations). The observations are remarkably accordant.

Bright Spot No. 4.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to March 29.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 19	14 29·0	323·5	1	11 19·3	−0·9	10 12 46·5	(*a*)
Mar. 20	12 54·4	289·7	3	21·2	+1·0	45·4	(*b*)
29	11 20·3	278·4	1	20·3	+0·1	45·2	(*c*)
Apr. 27	...	...	...	...	...	...	(*d*)
May 14	10 14·5	222·2	4	19·2	−1·0	45·9	(*e*)
17	(9 40·8)	(216·8)	...	(16·1)	(−4·1)	...	(*f*)
June 9	9 16·3	192·0	1	11 21·1	+0·9	10 12 46·5	(*g*)

Description.—(*a*) S, F, seen plainly. (*b*) S, F, well seen. (*c*) S, F, seen plainly. (*d*) Suspected. (*e*) S, m B, plain. (*f*) Obs. by Quénisset. (*g*) v S, v F, seen quite distinctly.

Mean period of rotation=10h 12m 45s·8±0s·14 (258 rotations). The accordance of the observations is very remarkable, none of the six observations made by the writer differing by more than one minute from the mean. The time of May 17 is derived from measures of a sketch made by M. Quénisset with the 9·4-inch refractor of the Juvisy Observatory.*

* *L'Astronomie*, 1893, p. 327, fig. 124.

Bright Spot No. 5.

Date.	G.M.T. of Transit.	Long.	Weight.	Obs. reduced to Apr. 8.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 4	13 27·5	111·0	1	10 61·9	+7·3	10 12 47·7	(*a*)
10	12 15·5	98·0	2	49·9	−4·7	57·9	(*b*)
18	14 19·0	89·6	1	50·7	−3·9	53·5	(*c*)
Apr. 8	10 51·1	69·9	1	51·1	−3·5	55·9	(*d*)
	11 0·9	75·6		60·9	+6·3		(*e*)
20	8 58·7	62·1	1	58·0	+3·4	54 8	(*f*)
May 10	8 52·0	34·6	3	45·2	−9·4	52·6	(*g*)
27	9 43·0	25·8	2	10 59·2	+4·6	10 12 59·9	(*h*)

Description.—(*a*) S, F, seen clearly but def. unsteady. (*b*) F, perhaps brighter. (*c*) S, F, seen plainly. (*d*) Obs. by Brown. (*e*) Obs. by MacEwen. (*f*) S, m B, seen brightly and plainly. (*g*) S, m B, seen brightly and plainly. (*h*) S, F, rather well defined.

Mean period of rotation=$10^h\ 12^m\ 55^s{\cdot}0 \pm 0^s{\cdot}98$ (197 rotations). The first observation of April 8 was made by Mr. G. L. Brown at Stirling, with a 10½-inch reflector. At 10^h the spot was seen about 30° east of the central meridian. The second observation is derived from measures of a sketch made by Mr. H. MacEwen at Glasgow, with a 5-inch refractor. As the two positions agree pretty well with each other, the mean of the two has been adopted in the calculations with weight 1.

Arranging the different bright equatorial spots in order of increasing longitudes, we have the following results :—

	No.	Period of Rotation.	No. of Rotations.
		h m s s	
Class C	5	10 12 55·0 ± 0·97	197
	2	10 13 1·8 ± 0·49	197
	3	10 12 58·3 ± 0·42	197
	1	10 12 59·4 ± 0·61	291
	4	10 12 45 8 ± 0·14	258

The first four spots evidently form a group, and combining the different values, the concluded period of rotation for Class C is $10^h\ 12^m\ 59^s{\cdot}36 \pm 0^s{\cdot}27$. The period of the last spot is more than 13^s shorter than this, so that we have here a similar difference to that existing between groups A and B of the dark northern spots, only here the difference is not so great. Spot No. 4 appears to be fairly representative of a somewhat extensive region. Hence, taking the date May 5 as the epoch, the surface material in the equatorial zone of *Saturn* rotated at the rate of $10^h\ 12^m\ 59^s{\cdot}36 \pm 0^s{\cdot}27$ between longitudes 0° and 140°;

whilst between longitudes 140° and 360° it rotated slightly more quickly, the average period of rotation here being represented by that of spot No. 4, namely, $10^h\ 12^m\ 45^s{\cdot}8$.

If we compare these figures with those indicated by the observations of 1892 and 1891, there has evidently been a continual acceleration in the motion of the bright equatorial spots, corresponding to a decrease in the period of rotation. Thus, adopting Mr. Marth's figures for the latter years, we have—

	h	m	s
Period of rotation in 1891 =	10	14	21·8
„ „ „ „ 1892 =	10	13	38·4
„ „ „ „ 1893 =	10	12	59·4

Similar changes are not uncommon in the case of the planet *Jupiter*, though they rarely occur quite so rapidly. For instance, in the case of one such change in the corresponding region of *Jupiter*, a period of eight years was required for an increase of half a minute in the period of rotation.

It is not clear at present in what manner these changes occur upon *Saturn*. They might take place—(1) by a steady or continual increase or decrease; (2) by sudden changes in the rate of motion analogous to those lately well observed in the case of *Jupiter*; * (3) by the old spots dying out and new ones successively making their appearance endowed with a swifter or slower motion. The first of these three ways may be dismissed at once, the observations showing that there has been no such continual change. So that the question would seem to come under one of the two latter.

Summary.

The principal conclusions derived from the foregoing discussion may be summarised as follows:—

(1) Between N. Kronocentric latitudes 17° and 37° the surface material of *Saturn* rotated in 1893 at the rate of $10^h\ 14^m\ 29^s{\cdot}07 \pm 0^s{\cdot}27$ between longitudes 45° and 140°, and at the rate of $10^h\ 15^m\ 0^s{\cdot}74 \pm 0^s{\cdot}56$ between longitudes 175° and 340°, whilst between longitudes 340° and 45° there was a region in which the surface material rotated at a rate intermediate between the above values.

(2) Between N. Kronocentric latitude 6° and about 2° S. latitude the surface material of *Saturn* rotated in 1893 at the rate of $10^h\ 12^m\ 59^s{\cdot}36 \pm 0^s{\cdot}27$ between longitudes 0° and 140°, whilst between longitudes 140° and 360° the rate of rotation was rather quicker, the average period of rotation here being well represented by that of spot No. 4, namely, $10^h\ 12^m\ 45^s{\cdot}8$.

* See *Observatory*, 1892, p. 110. In the case of one spot a change of over half a minute in the period of rotation occurred quite suddenly, and the region affected by the sudden change extended over more than 90° of zenographical longitude.

The above longitudes are referred to May 5 as a convenient epoch. The limiting Kronocentric latitudes have been kindly calculated by the Rev. A. Freeman from measures of two drawings of *Saturn* by means of the tables published by him in the *Monthly Notices*, vol. liv. p. 30.

Results of Micrometer Measures of Double Stars with the 12¾-inch Merz Refractor, at the Royal Observatory, Greenwich, during the year 1893.

(*Communicated by the Astronomer Royal.*)

Σ [OΣ]	Name.	R.A. 1900.	N.P.D. 1900.	Magnitude.		Position Angle.	Distance.	No. of nights.	Fraction of year 1893.
		h m	° ′			°	″		
180	γ Arietis	1 48·0	71 12	4·2	4·4	358·1	6·83	2	·097
305		2 41·7	60 10	7·3	8·2	317·1	2·83	1	·126
[82]		4 17·0	75 17	7·0	9·0	149·5	1·23	1	·170
535		4 18·0	78 52	6·7	8·2	324·7	1·17	2	·175
572		4 32·3	63 21	6·5	6·5	201·9	3·23	2	·128
577		4 35·4	52 41	7·7	7·7	71·6	1·64	2	·140
[92]		4 53·3	50 45	6·0	9·7	253·4	2·01	2	·184
[98]		5 2·4	81 39	6·0	6·8	188·6	1·05	4	·197
742		5 30·5	68 5	7·5	8·0	258·7	3·43	2	·205
749		5 30·9	63 9	7·1	7·2	167·4	1·14	2	·154
932		6 28·6	75 10	8·2	8·3	328·1	2·34	3	·184
[149]		6 30·3	62 38	6·5	9·0	284·3	0·88	2	·189
945		6 33·3	48 56	7·1	8·0	269·0	0·54	2	·240
982	38 Geminorum	6 49·0	76 42	5·4	7·7	160·7	6·77	2	·216
[165]	45 Geminorum	7 2·6	73 55	5·0	10·7	48·6	3·62	1	·285
1037		7 6·6	62 35	7·1	7·1	308·7	1·30	4	·159
[170]		7 12·2	80 31	7·5	7·5	112·4	0·74	3	·153
1066	δ Geminorum	7 14·2	67 50	3·2	8·2	206·8	7·37	2	·231
1074		7 15·4	89 25	7·8	8·2	144·4	0·75	2	·216
1081		7 18·1	68 21	7·5	8·5	226·4	1·69	2	·205
1104		7 24·9	104 47	6·5	8·0	328·3	2·23	2	·229
1110.	Castor	7 28·2	57 54	2·7	3·7	227·6	...	1	·101 *
						229·6	5·67	4	·186
[175]		7 28·6	58 51	6·0	6·6	329·9	0·50	3	·249
[176]		7 33·3	89 15	7·3	9·3	209·8	1·43	2	·241
[177]		7 34·7	52 21	7·5	8·5	124·3	0·51	3	·241
1126	Piazzi VII. 170	7 34·8	84 33	7·2	7·5	142·5	1·12	4	·206

Σ [OΣ]	Name.		R.A. 1900.	N.P.D. 1900.	Magnitude.		Position Angle.	Distance.	No. of nights.	Fraction of year 1893.
			h m	° ′			°	″		
[182]			7 47·4	71 45	7·0	7·5	31·9	1·26	2	·194
1157			7 49·8	92 31	8·0	8·0	...	0·89	1	·224 *
							257·3	0·88	2	·229 *
[185]			7 52 2	88 35	6·8	7·0	17·3	0·36	2	·241
1175			7 57·3	85 33	7·7	8 8	221·9	1·47	2	·228
[187]			7 57·7	56 41	6·9	7·5	285·2	0·34	3	·238
	β 581	A.B.	7 58 8	77 25	8·5	8·6	273·1	0·84	1	·309
1187			8 3·2	57 27	7·1	8·0	45·8	2 17	4	·141
1196	ζ Cancri	A.B.	8 6·5	72 3	5·0	5·7	26 5	1·05	2	·208
	„	A.C.	...	...	5 0	5·5	116·0	5·23	2	·208
	„	B.C.	...	...	5·7	5·5	131·3	5·17	2	·208
1202	Piazzi VIII. 13		8 8·1	78 50	7·7	9 8	321·1	2·18	2	·211
1211			8 11·1	50 52	9·1	9·6	309·7	0 74	2	·216
1216			8 16·3	91 16	7·5	8·2	183·6	0 35	3	·245
1223	ϕ^2 Cancri		8 20·7	62 44	6·0	6·5	217·0	4·35	2	·211
1224	ν^1 Cancri		8 20·7	65 8	6·0	7·1	41·7	6·13	3	·243
1228			8 21·6	62 5	8·3	8·9	350·4	9·27	2	·235
1243			8 28·9	88 2	8·0	9 7	225·5	1·53	2	·246
1263			8 38·5	47 55	7·6	8·2	20 2	49·91	1	·268
1273	ε Hydræ		8 40·5	83 13	3·8	7·8	224·7	3·28	4	·240
1291	57 Cancri		8 48 1	59 3	5·9	6·4	327·9	1·23	3	·244
1300			8 54·7	74 20	8 7	8 8	200·1	5·17	2	·234
3121			9 11·8	60 58	7·2	7·5	177·3	0·32	3	·265
1333			9 12·2	54 13	6·6	6·9	226 0	1·68	2	·234
1334	38 Lyncis		9 12·6	52 46	4·0	6·7	238·3	3·75	2	·244
1338			9 14·6	51 23	7·0	7·2	165·7	1·52	2	·277
[201]			9 17·9	61 33	7·5	9·0	226·5	...	1	·271 *
							219 5	1·50	2	·270 *
1348			9 19·3	83 13	7·5	7·6	324·5	1·40	3	·260
1355			9 22·1	83 19	7·2	7·2	333·8	2·30	3	·287
1356	ω Leonis		9 23·1	80 30	6 2	7·0	109·2	0·50	2	·274
1374			9 35·1	50 35	6·8	8·0	283·4	3·62	3	·300
1389			9 46 7	62 32	8·2	9·0	317·1	2·15	2	·304
1406			9 59·8	58 26	8·0	8·7	225·7	1·19	2	·303
[215]	Piazzi X. 23		10 10·5	71 45	7·0	7·2	209·5	0·95	2	·268
1424	γ Leonis		10 14·5	69 36	2·0	3·5	115·0	3·73	4	·301
1429			10 19·5	64 52	8·2	8·2	250·6	1·19	2	·268
[218]			10 22·1	85 54	7·3	9 2	90	0·3	1	·293

Σ [OΣ]	Name.	B.A. 1900.	N.P.D. 1900.	Magnitude.	Position Angle.	Distance.	No. of nights.	Fraction of year 1893.
		h m	° ′		°	″		
1439		10 24·6	68 41	8·0 8·5	118·4	1·62	3	·305
1450	49 Leonis	10 29·8	80 49	6·0 8·7	157·8	2·41	4	·324
1457		10 33·6	83 45	7·6 8·5	316·3	0·96	3	·342
[224]	Piazzi X. 128	10 34·5	80 39	7·2 9·2	306·0	0·61	2	·305
[228]		10 41·9	66 54	7·2 8·1	198·6	0·77	2	·385
[229]		10 42·2	48 21	6·7 7·1	330·4	0·67	2	·335
1476		10 44·2	93 28	7·2 8·0	66	1·98	1	·353
1504	Piazzi X. 229	10 59·0	85 50	7·5 7·6	290·4	1·10	2	·349
1517	Piazzi XI. 9	11 8·6	69 20	7·3 7·0	275·1	0·68	1	·361
1523	ξ Ursæ Maj.	11 12·8	57 54	4·0 4·9	187·7	1·76	4	·345
1527		11 13·8	75 11	7·0 8·0	18·5	3·73	3	·411
1534		11 16·7	71 16	8·0 11·2	...	5·36	1	·370 *
					324·7	5·61	1	·370
1536	*i* Leonis	11 18·7	78 55	3·9 7·1	59·6	2·55	2	·383
1555	Piazzi XI. 111	11 31·0	61 40	6·4 6·8	356·8	0·48	3	·347
[237]		11 33·7	48 18	7·4 9·0	266·4	1·21	3	·416
1606		12 5·8	49 33	6·3 7·0	335·7	1·07	3	·361
[250]		12 20·1	46 22	7·7 8·0	331·4	0·42	5	·376
1643		12 22·3	62 25	8·0 8·3	41·7	2·01	2	·357
1647		12 25·6	79 44	7·5 7·8	219·6	1·32	2	·363
1658	A.B.	12 30·1	82 0	8·0 9·8	358·3	2·98	2	·335
1658	A.C.	12 30·1	82 0	...	280·1	0·27	2	·335
1663		12 32·3	68 15	7·8 8·7	112·4	0·77	2	·358
1670	γ Virginis	12 36·7	90 54	3·0 3·0	151·7	5·86	2	·319
1687	35 Comæ	12 48·4	68 12	5·0 7·8	73·1	1·49	3	·371
[256]		12 51·4	90 25	7·2 7·6	267·5	0·39	2	·418
1728	42 Comæ	13 5·1	71 57	6·0 6·0	199·5	0·47	2	·409
[261]		13 7·5	57 24	6·9 7·4	344·2	1·42	3	·419
1734		13 15·6	86 33	7·2 7·9	195·0	1·15	2	·460
1742		13 19·3	88 4	7·4 7·9	349·4	1·42	1	·463
[266]		13 23·5	73 46	7·3 7·8	335·3	1·54	2	·387
1757	Piazzi XIII. 127	13 29·2	89 48	7·8 8·9	80·0	2·63	2	·415
1777	84 Virginis	13 38·0	85 57	5·8 8·2	233·8	3·18	2	·427
1781		13 41·2	84 23	7·8 8·2	278·7	1·32	3	·462
	β 612	13 34·8	78 42	6·4 6·5	193·1	0·39	1	·468
1808		14 5·3	62 56	8·2 9·0	71·9	3·71	1	·463
1819		14 10·3	86 26	7·9 8·0	4·7	1·12	1	·468
1834		14 16·6	41 1	7·1 7·2	145·5	0·39	1	·468

Σ [01]	Name.	R.A. 1900.	N.P.D. 1900.	Magnitude.	Position Angle.	Distance.	No. of nights.	Fraction of year 1893.
		h m	° ′		°	″		
1865	ζ Bootis	14 36·4	75 31	3·5 3·9	105·4	0·52	3	·488
1867		14 36·7	58 17	7·7 8·2	15·2	1·43	3	·455
1877	ε Bootis	14 40·6	62 30	3·0 6·3	328·8	2·63	2	·488
1888	ξ Bootis	14 46·7	70 29	4·7 6·6	235·5	3·70	4	·457
	β 31	14 7·8	70 52	8·4 9·7	196·3	1·87	4	·464
[287]		14 47·9	44 40	7·5 7·6	321·8	0·94	1	·493
[288]		14 48·5	73 53	6·4 7·1	191·3	1·68	2	·470
1932		15 14·1	87 52	5·6 6·1	137·3	0·92	2	·497
1937	η Coronæ	15 19·0	59 21	5·2 5·7	245·3	0·85	3	·497
1938	Piazzi XV. 74	15 20·8	52 18	6·7 7·3	82·9	1·26	1	·501
[296]		15 23·1	45 40	7·0 8·6	310·5	1·55	2	·479
1954	δ Serpentis	15 30·0	79 9	3·2 4·3	187·3	4·12	1	·496
[298]		15 32·5	49 52	7·0 7·3	170·6	1·03	1	·457
[303]		15 56·1	76 26	7·4 7·9	137·5	...	1	·466 *
					135·2	0·56	1	·466 *
2140	α Herculis	17 10·1	75 30	3·0 6·1	121·0	4·87	1	·731†
2203		17 38·3	48 17	7·5 7·8	328·2	0·93	1	·690
2215		17 41·1	72 15	5·9 7·9	164·1	0·39	1	·690
2272	70 Ophiuchi	18 0·4	87 28	4·1 6·1	308 9	2·34	1	·690

The measures were made with a position-micrometer on the 12¾-inch Merz refractor, which is mounted on the Lassell equatorial. In general the power of the eye-piece used was 412.

The measures were made, except where specially noted, by Mr. Lewis.

Measures marked * were made by Mr. Turner, those marked † by Mr. Edney.

The approximate positions are for the year 1900, and the magnitudes have been taken from Struve and Otto Struve.

Royal Observatory, Greenwich:
1894 *March* 9.

New Orbit of 9 Argûs, β 101. By Professor S. Glasenapp.

(*Communicated by T. Lewis.*)

In the article "Orbit of 9 *Argûs*, β 101," published in vol. lii. No. 8 of the *Monthly Notices of the Royal Astronomical Society*, I have communicated the elements of this close double star. These elements present a fairly good agreement with the observations, especially for the angles of position, but in the distances the last observation (0″·22) gives a discordance of 0″·16 with the calculated distance, which is 0″·38.

This circumstance was mentioned by Mr. S. W. Burnham, M.A., in an article published in the journal *Astronomy and Astrophysics*, No. 116; where, supposing that the position of the satellite for the year 1875 must be changed as follows—

instead of	1875·71 $\theta = 289°·7$ $\rho = 0''·46$
it must be	1875·27 $\theta = 289°·7$ $\rho = 0''·58$

he draws another ellipse with a larger eccentricity. I admit that these corrections made by Mr. Burnham are very probable. If we adopt them, and take his apparent ellipse, we obtain a new set of elements; if, then, we determine their corrections by the method of least squares, we obtain the following most probable elements of 9 *Argûs*:—

T = 1892·27	λ = 73°·70
P = 23·33 years	$i = 77°·73$
$n = +15°·430$	$e = 0·668$ ($\phi = 41°·943$)
Ω = 97°·54	$a = 0''·60$

I give in the next table the comparison of these elements with the observations (see the above-mentioned note in the M.N.):—

t	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
	°	°	°	″	″	″
1875·24	289·7	290·0	−0·3	0·58	0·58	0·00
78·50	302·2	300·0	+2·2	0·45	0·48	−0·03
79·68	306·2	305·1	+1·1	0·38	0·42	−0·04
82·21	319·7	323·4	−3·7	0·35	0·29	+0·06
83·11	336·2	334·6	+1·6	0·30	0·24	+0·06
89·08	76·4	76·0	+0·4	0·34	0·32	+0·02
90·22	83·8	84·7	−0·9	0·34	0·35	−0·01
91·06	91·5	90·6	+0·9	0·34	0·34	0
92·05	98·7	100·1	−1·4	0·21	0·25	−0·03

The sum of the squares of the residuals is largely reduced; indeed, for our first set of elements it was 52·31 for θ and 0·0342 for ρ. For the new elements we have 26·13 for θ and 0·0111 for ρ.

In both angle and distance the sum of the squares has diminished very considerably. Therefore the new system of elements must be considered as representing much better the true orbit of 9 *Argûs*.

With these new elements the following positions of the satellite for several years have been calculated:—

	θ	ρ		θ	ρ
	°	"		°	"
1894·0	273·8	0·32	97·0	285·9	0·57
95·0	279·6	0·46	98·0	288·5	0·58
96·0	283·1	0·54	99·0	291·1	0·57

The angular velocity is increasing, and between 1892 and 1894 the angle of position has changed 180°; therefore each observation obtained during the present and next years will be of great value for the investigation of the orbit; but 9 *Argûs* belongs to the most difficult double stars, and is accessible only to the most powerful telescopes placed in perfect conditions.

St. Petersburg,
Observatory of the Imperial University:
1894 *March* 4.

On the Proper Motion of Stars in the Dumbbell Nebula. By Professor Arthur A. Rambaut, M.A., Sc.D., and W. E. Wilson, F.R.A.S.

Most photographs of the Dumbbell Nebula in *Vulpecula* (M. 27, N.G.C. 6853) represent the brighter portion of it as being of a sort of hour-glass form or approximately the figure which would be formed by two opposite sectors of a circle of about 60° each. The stars, too, which are found in the nebula are not distributed wholly without relation to the form of the latter, for it is a remarkable fact that exactly at the common centre of the two sectors, or the neck of the hour-glass, a comparatively conspicuous star is placed, while the extremities of each of the bounding arcs are approximately indicated by stellar points. These stars are respectively *d*, *a*, *m*, *o*, and *c* in the figure.

In the *Philosophical Transactions of the Royal Society*, Vol. 151, Part III., the Earl of Rosse publishes a note on the positions of twenty-six stars as determined at the Poulkova

Observatory by M. Otto Struve, in which the latter expresses his conviction that the probable error in the coordinates will be considerably less than one second of arc. As some of these stars lie outside the region over which the nebula extends on the photographs or that which it occupies on the Parsonstown drawing it appears an interesting inquiry whether those stars apparently related to the nebula indicate any proper motion, as compared with those lying outside it, in the forty-two years which have elapsed since M. Struve's measures were made.

In order to investigate this question we measured two photographs taken with the 2-foot equatorial reflector belonging to Mr. Wilson on 1893 September 3 and 8, with exposures of 27^m and 2^h respectively.

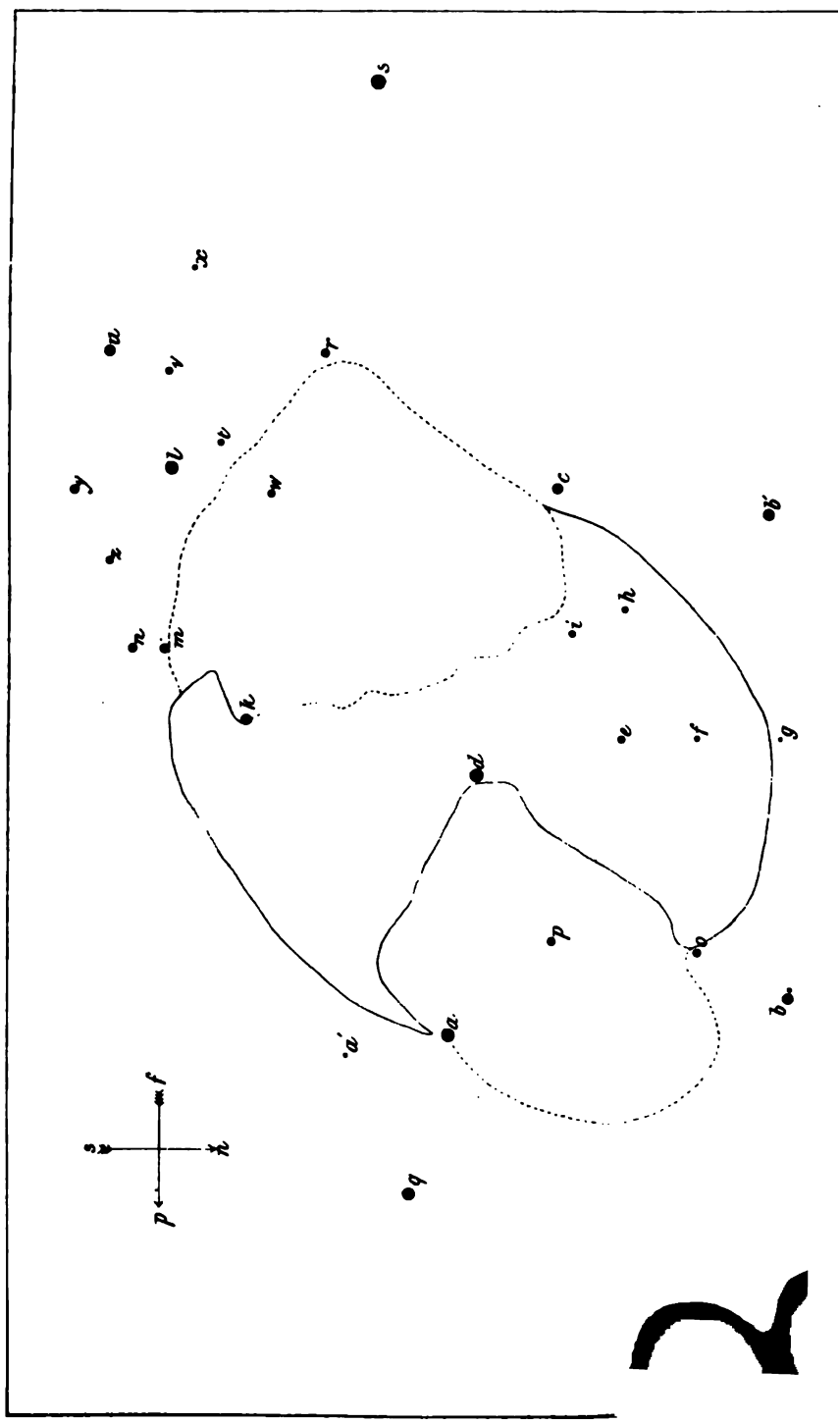
The plates were examined in the measuring microscope of the Dunsink Observatory, in which the coordinates are determined on two screws at right angles to each other. The plates were placed in position in the microscope by means of the relative positions determined by M. Struve for the stars *a* and *s* of his list, so that each screw was parallel to one of the axes of coordinates employed by that astronomer. The scale value of the photograph, too, was determined from the value of $\Delta\alpha \cos\delta$ given by him for the same stars, which, depending as it does on a larger number of observations than the other measures, is the best determined interval in the group, besides being very nearly the longest. Consequently any error affecting its length will be felt to a smaller extent in the measures of any other interval.

Our coordinates are thus directly comparable with those of M. Struve, our axis on the plate being, by the above process, set in the direction of the parallel passing through *a* at the date of his observations. The correction for refraction has not been applied, as it was found that in no case would its effect amount to a tenth of a second of arc, and the measures, though probably correct to within two or three tenths of a second, could hardly be relied on to a higher degree of accuracy.

A comparison of our results with those obtained by Mr. Bindon Stoney, using the 6-foot reflector belonging to the Earl of Rosse, and with those of M. Struve, is given in Table II. The former cannot be depended on with any high degree of precision on account of a difficulty in determining the parallel arising from the altazimuth form of the great reflector. They are, however, given in the table, as in several cases they point to the existence of a proper motion in the same direction as is deduced from a comparison of our measures with those of M. Struve.

It will be seen from the columns headed $X_s - X_w$ and $Y_s - Y_w$ that in most cases there are discrepancies which can hardly be attributed to errors of observation. These would indicate in the case of the stars *p*, *d*, *k*, *i*, *b'*, and *y* proper motions amounting in forty-two years to $4''{\cdot}6$, $3''{\cdot}9$, $5''{\cdot}7$, $6''{\cdot}0$, $5''{\cdot}2$, and $5''{\cdot}3$ respectively.

It does not seem, however, that there is any obvious relation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between the position which a star bears with regard to the nebula and the amount or direction of its proper motion, but further observations will be necessary to decide this point.

In the accompanying plate the positions of the stars are plotted down from our measures, and the form of the nebula is indicated in outline to facilitate the identification of the stars.

TABLE I.—*Coordinates of Stars in the Dumbbell Nebula.*

Name.	X	Y	Name.	X	Y
q	− 94″·4	− 20″·6	*k*	+ 247″·1	+ 102″·6
	94·4	20·6		246·7	104·4
	− 94·4	− 20·6		+ 246·9	+ 103·5
a'	− 9·9	− 58·1	*z*	276·6	− 197·1
	9·2	56·8		275·9	196·8
	− 9·6	− 57·5		276·3	− 197·0
b	+ 21·9	+ 199·1	*b'*	302·8	+ 187·5
	22·7	199·2		303·4	186·8
	+ 22·3	+ 199·1		303·1	+ 187·2
o	47·5	+ 145·5	*w*	316·2	− 102·7
	49·0	145·6		315·8	101·2
	48·2	145·5		316·0	− 102·0
p	56·4	+ 59·6	*c*	317·6	+ 63·9
	56·9	60·6		317·2	64·3
	56·6	+ 60·1		317·4	+ 64·1
d	151·7	+ 16·9	*y*	317·2	− 216·5
	151·3	16·3		317·4	217·1
	151·5	+ 16·6		317·3	− 216·8
e	169·8	+ 99·9	*l*	328·5	− 160·5
	169·5	100·5		328·2	160·2
	169·7	+ 100·2		328·4	160·4
g	171·9	+ 192·8	*t*	345·3	− 132·2
	172·3	193·0		344·4	131·3
	172·1	+ 192·9		+ 344·9	− 131·8

Name.	X	Y	Name.	X	Y
f	171″4	+146″9	*t*	+386″9	−162″3
	170·8	146·6		387·2	161·5
	171·1	+146·8		387·0	−161·9
k	183·0	−116·7	*r*	396·6	− 72·8
	182·5	117·3		396·6	72·5
	182·8	−117·0		396·6	− 72·7
n	223·3	−183·7	*u*	398·9	−198·0
	222·8	184·1		398·9	−198·2
	223·1	−183·9		398·9	−198·1
m	223·6	−163·7	*x*	442·3	−146·7
	222·7	164·2		442·7	145·6
	223·2	−163·9		442·5	−146·2
i	232·8	+ 73·6	*s*	555·8	− 41·7
	233·1	75·0		555·8	− 42·2
	232·9	+ 74·3		+555·8	− 41·9

TABLE II.—*Comparison of Measures.*

Name.	*Wilson.* X_W	Y_W	*Rosse.* X_r	$X_r - X_W$	Y_r	$Y_r - Y_W$	*Struve.* X_s	$X_s - X_W$	Y_s	$Y_s - Y_W$	
	″	″	″	″	″	″	″	″	″	″	
q	− 94·4	− 20·6	...	...	...	...	− 97·6	−3·2	− 20·9	−0·3	
a'	− 9·6	− 57·5	− 10·9	−1·3	− 59·8	− 2·3	− 12·3	−2·7	− 57·2	+0·3	v. v. f.
h	+ 22·3	+199·1	+ 23·0	+0·7	+199·7	+ 0·6	+ 21·6	−0·7	+199·7	+0·6	
o	48·2	+145·5	46 8	−1·4	+149·5	+ 4·0	+ 49·6	+1·4	+144·0	−1·5	
p	56·6	+ 60·1	48·1	−8·5	+ 61·3	+ 1·2	+ 60·6	+4·0	+ 57·9	−2·2	Ill defined.
d	151·5	+ 16·6	154·4	+2·9	+ 17·5	+ 0·9	+152·5	+1·0	+ 12·8	−3·8	=*a* in mag.
e	169·7	+100·2	172 8	+3·1	+ 98·6	− 1·6	+172·5	+2·8	+ 98·8	−1·4	
g	172·1	+192·9	173·9	+1·8	+193·2	+ 0·3	+174·3	+2·2	+191·5	−1·4	v. v. f.
f	171·1	+146·8	172·3	+1·2	+144·5	− 2·3	+174·6	+3·5	+142·2	−4·6	
k	182·8	−117·0	187·4	+4·6	−121·3	− 4·3	+186·8	+4·0	−121·0	−4·0	
n	223·1	−183·9	...	...	...	...	+224·9	+1·8	−184·7	−0·8	
m	223·2	−163·9	...	...	...	...	+225·0	+1·8	−164·3	−0·4	
i	232·9	+ 74·3	235·8	+2 9	+ 70·8	− 3·5	+238·2	+5·3	+ 71·5	−2·8	>*h*.
h	246·9	+103·5	246·2	−0·7	+100·5	− 3 0	+251·1	+4·2	+101·7	−1·8	v. nebulous.
c	276·3	−197·0	...	...	...	...	+279·6	+3·3	−199·7	−2·7	
b'	303·1	+187·2	303·6	+0·5	+183·4	− 3·8	+308 3	+5·2	+186·3	−0·9	
w	316·0	−102·0	323·5	+7·5	−115·0	−13·0	+317·7	+1·7	−102·0	0·0	
o	317·4	+ 64·1	325·3	+7·9	+ 63·1	− 1·0	+321·1	+3·7	+ 62·8	−1·3	
y	317·3	−216·8	...	...	...	...	+321·8	+4·5	−219·5	−2·7	
l	328·4	−160·4	...	...	...	...	+332·4	+4·0	−162·2	−1·8	
t	344·9	−131·8	...	...	...	...	+347·8	+2·9	−128·9	+2·9	Ill defined.
v	387·0	−161·9	...	...	...	...	+390·7	+3·7	−161·7	+0·2	
r	396·6	− 72·7	398·2	+1·6	− 91·6	−18·9	+396·9	+0·3	− 74·0	−1·3	
u	398·9	−198·1	...	...	...	...	+402·4	+3·5	−200·8	−2·7	
x	442·5	−146·2	...	...	...	...	+442·0	−0·5	−148·5	−2·3	v. v. f.
s	+555·8	− 41·9	...	...	...	...	+555·8	0·0	− 42·0	−0·1	

Note on the Star DM + 27°·725. By A. M. W. Downing, M.A., D.Sc.

This star was selected as one of the *Nautical Almanac* zodiacal stars on the authority of the Harvard Photometry, where it appears as No. 893 of the General Catalogue, with magnitude 6·3. The magnitude 5·9 assigned to the star in the DM is a misprint for 9·5, as is explained in *B. B.* vi. p. 378.* And as a tolerably comprehensive search failed to find the star in any modern catalogue it appears probable that the Harvard observations, assigned to this star, really refer to some other object. This view is confirmed by the evidence afforded by a photographic plate which the Astronomer Royal most kindly had taken for the express purpose of identifying the star. It was found, on examining the plate, that the object nearest the assigned place was fainter than the 9th mag. Professor Pickering has also been so good as to furnish information bearing on the subject derived from photographs taken on 1890 December 29, 1892 January 8 and December 28, and 1893 October 5. On these plates the star appears to be of about the 10th mag., and shows no evidence of variation. It may be concluded, therefore, that the mag. 9·5 assigned to this star by the Bonn observers is correct, and that the Harvard measures refer to some other object.

That the object measured at Harvard College was not the neighbouring star DM + 27°·723 appears probable from the results of measures of the latter object which Professor Pickering has kindly communicated. The mean of four measures gives 6·6 as the magnitude of this star.

The star DM + 27°·725 ought not, therefore, to have been included in the *Nautical Almanac* list of zodiacal stars (which is restricted to stars of magnitude not fainter than 6·5), and should be struck out wherever it appears in the Occultation Section of the *Nautical Almanacs* for 1896 and 1897, as well as in the Catalogue of Zodiacal Stars printed in the appendix to the last-named volume.

Nautical Almanac Office :
1894 *March* 5.

* Mr. Chandler also points this out in *Ast. Nach.* No. 3214.

On the Spectra of Certain Stars (Second communication). By the Rev. T. E. Espin, M.A.

(1) DM + 49°·41. R.A. $0^h\ 12^m{\cdot}2$. Decl. + 49° 44′ (1900). Mag. 9·0. The spectrum of this star was found to be IV. type at Harvard. As this star has not been observed visually, as far as I am aware, it was looked up Dec. 11, and found to be fine red, Spectrum IV.! The bands are very well seen. Mag. 8·6.

(2) Anonymous. R.A. $0^h\ 16^m{\cdot}8$. Decl. + 58° 36′ (1900). A star found October 8, not in Argelander. The colour is fine red, and the spectrum banded, but too faint to be sure whether it is type III. or type IV. As it was not in Argelander, and not recorded in previous sweeps, it has been watched for variation. The following are the observations of it:—

October 8, Mag. 10·0.
October 11, Mag. 9·7.
October 19, Mag. 9·7.
December 30, Mag. 9·5.

The star may therefore have brightened slightly.

(3) Anonymous. R.A. $2^h\ 10^m{\cdot}0$. Decl. + 58° 3′ (1900). Found December 11. Not in Argelander. Mag. 9·0. Pale red. Spectrum III. type. The comparison of photographs 1893 January 20, 26, December 12, shows no variation.

(4) *T Persei.* R.A. $2^h\ 12^m{\cdot}2$. Decl. + 58° 59′ (1900). As this star has not been observed with the spectroscope, it was set for on December 11, and found to be mag. 8·6. Colour red. Spectrum III. !!! The bands are large, but not deep. The spectrum is similar to many stars in this region. I have found no part of the heavens where so many red stars are congregated. If a circle with about 1° radius is drawn with centre R.A. $2^h\ 10^m$, Decl. 57°25′ (1855), it will include fourteen stars of type III.

(5) DM + 56°·731. R.A. $2^h\ 44^m{\cdot}8$. Decl. + 56° 32′ (1900). Mag. 9·5. This is a star of type V. discovered by photography at Harvard. I have observed it on several occasions, and it always appeared to have a monochromatic spectrum. On December 11 I reobserved it. There is a very faint continuous spectrum. Calling the total light of the star 10, the bright line at or near F would equal 9, the continuous spectrum 1. There is also an inequality in the spectrum, probably the usual one at 540. The bright line is remarkably vivid, and appears to project beyond the spectrum. Whether this is due to irradiation or actual projection I am unable to tell.

(6) DM + 61°·734. R.A. $4^h\ 40^m{\cdot}1$. Decl. + 61° 0′ (1900). Mag. 7·7. This star was discovered by Mr. Gage with his 15-inch reflector at Wolsingham. He informed me that it had a fine III.-type spectrum. It was observed by me 1894 Jan. 7, and found to be mag. 7·5. Colour orange red. Spectrum

III. ! ! ! The spectrum is normal; all Dunér's bands are seen. The bands at the violet end are intense, and the spectrum here is discontinuous.

(7) Var. R.A. $19^h\ 9^m{\cdot}6$. Decl. 49°29′ (1900). A star not in Argelander. Announced as variable by Deichmüller (*A.N.* 3191). Observed December 14 in moonlight as 8·8 mag. Colour red. Spectrum III. ! ! Faint in moonlight. The bands seem to be deep in the violet end, and the spectrum is here discontinuous. When the spectrum is brought to a line, it is beaded with bright dots.

(8) DM + 24°·3902. R.A. $19^h\ 46^m{\cdot}3$. Decl. + 24°41′ (1900). Mag. 9·2. First seen October 11. Mag. 8·7. Very red; banded spectrum. I think III. November 13, 8·9 mag.

(9) χ *Cygni*. R.A. $19^h\ 46^m{\cdot}7$. Decl. + 32° 40′ (1900). August 12, mag. 9·0. Perfectly discontinuous III.-type spectrum. There seems to be nothing but a few bright isolated bands. Colour very red. August 14, mag 9·1; very red. The spectrum quite discontinuous; one bright band stands out near centre of the spectrum far brighter than the rest; others are, however, seen. Allowing for the faintness of the light, the spectrum seems similar to what it is at maximum.

(10) Var. R.A. $20^h\ 47^m{\cdot}4$. Decl. + 45° 50′ (1900). An anonymous star, announced as variable by Wolf. December 9, mag. 9·0; red. There are bands, and I think they are those of type III.

(11) *Es. Birm.* 696 = DM + 45°·3349. R.A. $20^h\ 54^m{\cdot}5$. Decl. + 46° 5′ (1900). Mag. 8·1. My observations of the spectrum of this star differ strangely. 1888 May 4 I noted that the blue and violet are singularly faint, and the spectrum very unpronounced for so finely coloured a star, sometimes thought to be III., sometimes IV. May 9, III.! 1891 October 2, III.! ! ! November 26, III. 1893 September 9, III.! ! There is no doubt about the spectrum; the bands are large and faint. The photographs suggest unsteadiness of light. My observations of the magnitude are—

1885 December 15, 25, 8·0 mag.
1886 January 15, June 30, August 20, 8·0 mag.
1891 October 2, 8·5 mag.
1891 November 26, 8·3 mag.
1893 September 9, 7·6 mag.
1893 September 11, 8·0 mag.
1893 September 12, 8·2 mag.
1893 September 14, 8·1 mag.
1893 September 16, 8·2 mag.
1893 September 19, 8·2 mag.
1893 September 27, 8·3 mag.
1893 November 13, 8·2 mag.

The variation seems very doubtful.

(12) DM + 57°·2487. R.A. $22^h\ 10^m{\cdot}5$. Decl. + 57° 31′ (1900). Mag. 9·1. October 6, mag. 9·0; very red; the bands are very large, and at first it was thought to be IV., but afterwards I was convinced that it was III. ! ! ! The spectrum is quite discontinuous, and some of the bands are of unusual size.

Some Nebulous Objects not in the New General Catalogue of Nebulæ. By the Rev. T. E. Espin, M.A.

While sweeping for red stars I have encountered various nebulous objects. These have been carefully marked on the chart of Argelander of that region, estimating their position from the neighbouring stars. Most of these were subsequently found in the New G.C. of Nebulæ. The following are, however, new. In several cases they are partially resolved, and may really be gatherings of very faint stars. The places which are approximate only, but which are probably correct to within 10^s of R.A. and 3′ of Decl., have been brought up to 1860.

(1) R.A. $19^h\ 16^m\ 33^s$ Decl. + 20° 29′. Probably a cluster of very faint stars. October 8.
(2) R.A. $19^h\ 30^m\ 46^s$ Decl. + 40° 44′. Faint nebulosity. October 6.
(3) R.A. $19^h\ 33^m\ 8^s$ Decl. + 19° 54′. Very faint, extending N.P. from a 9·5 mag. star. October 8.
(4) R.A. $19^h\ 36^m\ 43^s$ Decl. + 37° 19′. Nebula round a group of faint stars. September 16.
(5) R.A. $19^h\ 37^m\ 5^s$ Decl. + 27° 10′. While sweeping on September 14 I suddenly came upon a dark space. On carefully examining the field there is evidently a large faint nebulosity, mixed up with stars, sharply defined on *f* side, stretching N. and S. Max Wolf's photograph shows this nebulosity.
(6) R.A. $20^h\ 4^m\ 43^s$ Decl. + 34° 33′. Faint nebulosity. September 19.
(7) R.A. $20^h\ 6^m\ 0^s$ Decl. + 40° 46′. Extremely faint nebula within a circle of bright stars. October 6.
(8) R.A. $20^h\ 11^m\ 42^s$ Decl. + 24° 45′. Large, misty patch, partly resolved. October 8.
(9) R.A. $21^h\ 5^m\ 39^s$ Decl. + 46° 17′. Faint, extending N. from DM + 46°·3214, 9·4 mag. September 9.
(10) R.A. $21^h\ 7^m\ 12^s$ Decl. + 47° 11′. Faint, large, many small stars. September 9.
(11) R.A. $21^h\ 18^m\ 44^s$ Decl. + 54° 51′. Faint, diffused, some faint stars. September 16.
(12) R.A. $21^h\ 39^m\ 19^s$ Decl. + 52° 18′. Misty patch, partly resolved. September 16.

(13) R.A. $21^h\ 39^m\ 59^s$ Decl. + 52° 37′. Faint, partly resolved; stars 14 mag. September 16.

(14) R.A. $22^h\ 5^m\ 21^s$ Decl. + 52° 8′. A remarkable cluster with six distinct radiating branches. Stars from 12 to 15. Very beautiful. September 19.

(15) R.A. $22^h\ 11^m\ 11^s$ Decl. + 53° 21′. Haze round some dozen faint stars.

Description of a Perfectly Achromatic Refractor.

By H. Dennis Taylor.

Now that photography is becoming such an indispensable supplement to eye observation in astronomical work, the need for a form of refracting telescope which is perfectly corrected for photographic as well as for visual purposes becomes more and more apparent. And if, simultaneously with that condition, a great improvement in the character of the visual image can also be obtained, then we have the elements of a very substantial improvement in the refractor. In a paper which I had the honour of reading to this Society in November last I pointed out the considerable loss of light for defining purposes which must take place, owing to the usual colour aberrations ever present in the case of double object glasses made of ordinary crown and flint glasses. I there gave the losses of light, as determined by a theoretical method, for certain objectives of various sizes. Since then I have been able to carry out a delicate experiment with a 12½-inch object glass, whereby the amount of light lost owing to the colour aberrations was separated from the real image, and rendered approximately measurable. The result certainly confirmed the figures giving percentage of light lost, which I had previously arrived at by an *à priori* line of reasoning. I hope to have the pleasure of describing this experiment in a future paper. Thus I feel justified in saying that the principal improvement in the visual image to be expected from the almost perfect achromatism attained in this new objective is a more brilliantly defined image, the fine details being rendered in more black and white contrast than we have been accustomed to see, thus standing out, in an artistic sense, with greater sharpness. For this new objective is to all intents and purposes as achromatic as a reflecting telescope. My justification for this statement is as follows:—

It must be remembered that in practice the reflecting *telescope*, mirror and Huyghenian eye-piece combined, is not absolutely achromatic. However absolute may be the achromatism of the primary image, yet the eye-piece, if of the Huyghenian or Ramsden type, always introduces its own colour aberrations. Taking the case of a Huyghenian eye-piece of 1 inch equivalent

focal length, the virtual longitudinal colour aberration from B to Hγ (G′) which it would introduce would amount to about three-hundredths of an inch. This amount in the case of a reflector of a focal length equal to seven and a half times its aperture is about equal, as regards detriment to vision, to a longitudinal colour aberration of six-hundredths of an inch in the case of either a reflector or a refractor of a focal length equal to fifteen times its aperture. I shall shortly point out that in the case of even an objective of 2 feet aperture, and of 36 feet focal length, of the new construction, the residual longitudinal colour aberrations need not be expected to amount to as much as six-hundredths of an inch; while at the same time an achromatic single lens eye-piece may be employed, presenting no spectrum and having only two reflecting surfaces. Or, supposing a 1-inch Huyghenian eye-piece to be generally employed on such a telescope, the objective may be sufficiently over-corrected to counteract the longitudinal colour aberrations of that eye-piece.

The problem of devising a perfectly achromatic objectglass has occupied the attention of many scientific men and opticians for a considerable time. The Rev. Vernon Harcourt spent twenty-five years or so of his life in melting and trying new forms of glass with a view to producing two glasses of similar rationality. But none of his experiments resulted in practical success. The problem has also deeply occupied the attention of Sir G. G. Stokes and the late Professor Pritchard. In short, it is a problem which has exerted a great fascination over many minds. Some, notably Professor Hastings in America, and Professor Abbe of Jena, fully realised that 'practical success need not by any means depend upon the employment of only two lenses in the objective. Professor Hastings published an article in the *American Journal of Science and Art* (for December 1879) in which he gave the results of calculations of several forms of objectives made of three kinds of glass, in some of which a remarkably near approach to perfect achromatism seemed to be possible. However, none of these combinations seem to have been worked into practical shape, and, so far as I know, principally because one or other of the glasses employed—all, I believe, the production of Mons. Feil of Paris—could not be made hard enough or durable enough for practical use.

In 1884 the justly celebrated firm of Herren Schott und Ges started their optical glass manufactory at Jena for the principal purpose of making both old and new varieties of optical glass on a commercial scale, at the same time addressing themselves in a most thorough and scientific manner to the problem of producing two glasses whose rationality of dispersion should be identical, at the same time that the difference between their dispersive powers should be sufficient to enable a perfectly achromatic double object glass to be constructed, without having to resort to impracticably deep curves.

But in spite of the skill and scientific method brought to bear upon this problem, and exhaustive trials of all known substances capable of being fused into glasses, it cannot be said that that aim has been realised; and I really believe that a practicable *double* object glass, even reasonably free from secondary colour aberration, is as far from being realised as it was ten years ago. For it should be borne in mind, when aiming at an object glass of two glasses which shall be perfectly achromatic, that although it may be possible to considerably reduce the discordance between their respective rationalities of dispersion, yet the reduction of secondary spectrum at the focus accruing from that improvement may be largely counteracted or even wholly neutralised by the deeper curvatures or higher powers of the two component lenses, which are rendered necessary by that smaller difference of dispersive powers of the two glasses which has hitherto inevitably accompanied the closer agreement in rationality of dispersion. In short, whether using two or three lenses, the deeper the curves, or the more powerful the component lenses, required for obtaining a given focal length, the more close and strict must be the concordance of rationality of dispersion between the glass (or two glasses combined) forming the positive element and the glass forming the negative element of the objective. To be sure, certain double combinations have been made in which the secondary spectrum has been reduced to about half the usual amount. For instance, Dr. Czapski of Jena * describes a form of objective of which two or three were made by Bamberg of Berlin, and also, I believe, by Dr. Czapski himself, in which the positive lens was made of Schott's dense barium phosphate crown S ·30, and the negative lens of Schott's borate flint S ·8 or S ·7. This is somewhat similar to a combination of the same flint with a nearly similar crown which was carried out by Messrs. Cooke about seven years ago, and found to make a more than usually achromatic object glass. But the borate flints are too soft for practical purposes, and, moreover, Dr. Schott has informed us that it is almost impossible to get good discs of this glass of over 5 inches aperture.

A few years ago Professor Hastings patented in America another form of double object glass in which the secondary spectrum was reduced to about half. For his positive lens he made use of potassium silicate crown (Schott's 0·13), and for his negative lens Schott's boro-silicate flint glass 0·161. This combination turned out to be impracticable: the crown is too hygroscopic, and the flint, Dr. Schott has informed us, cannot be made good enough.

Having considered all the facts of the case, I was inevitably

* In Dr. Czapski's work, *Theorie der optischen Instrumenten* (*nach Abbe*), on page 131, will be found graphic diagrams showing the somewhat reduced amounts of secondary spectrum exhibited by these combinations as compared with that exhibited by an ordinary object glass of crown and dense flint.

led, as a few other inquirers have been led, to the conclusion that there was little prospect of making an object glass of two lenses whose achromatism would be so much superior to that of the ordinary objective as to fully compensate for the other practical disadvantages which would ensue, either in the shape of curves difficult to work or a confined field of view, not to mention several other serious drawbacks.

Some two years ago I entered into an investigation as to the possibility of producing a triple object glass, free from secondary spectrum, whose curves should be such as to permit of all the other necessary or desirable optical qualities and certain practical advantages being attained. After a very searching and prolonged trial of all the likely combinations of glasses picked out of the numerous new and old types of glass, put at the disposal of the optical world by the genius of Dr. Schott and Professor Abbe, and by help of every opportunity for investigation and experiment afforded me in the workshops of Messrs. Cooke, I at last realised a triple combination of three different sorts of glass, which, while yielding a degree of achromatism almost greater than anything which I had at first ventured to hope for, at the same time rendered possible the achievement of certain other important optical qualities and practical conveniences which yet remain to be specified.

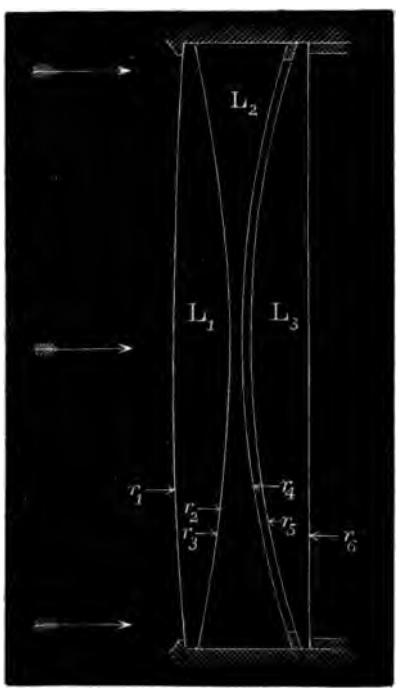
Taking the optical qualities first—

1. This objective can be made free from spherical aberration for all colours simultaneously. This is of the utmost importance in the case of an objective having any pretensions to perfect achromatism. In a double objective of ordinary construction having a double concave or concavo-plane flint lens, it it well known that when the brightest yellow green rays are perfectly corrected for spherical aberration, then the red rays are under-corrected, and the blue rays are over-corrected for spherical aberration; a condition of things, however, which escapes notice in the presence of the greater fault of the secondary spectrum.

2. The objective is so arranged as to give the largest possible field of good definition. The image of a star formed at, say, 2° from the optic axis is free from coma or side flare, and also from colour. If a star is focussed into the centre of the eye-piece and the objective is tilted, even very considerably, then the image of the star remains symmetrical and without side flare, and only showing the inevitable astigmatism. This condition is of the utmost importance in the case of an objective when used for photographing celestial objects having considerable angular extension, or for transit instruments which are generally provided with eye-pieces having a certain amount of lateral travel.

3. The curves are also such that a ray parallel to the optic axis traced through the margin of the objective enters and leaves the flint lens at approximately equal angles. This is of con-

siderable importance in the case of deep curves, and especially in large-sized objectives, because the flint lens is by a long way the weakest, in a mechanical sense, of the three lenses, and therefore most liable to flexure across its diameter, and such flexure would in the large sizes, and under ordinary circumstances, give rise to considerable aberrations of the marginal rays from true focus. But if refraction of such marginal rays takes place about *equally* at both surfaces, then the optical results of such flexure or sagging of this lens are reduced to practically nothing. The action of the edge of the flint lens upon the marginal rays is in this case the same as that of a prism when set at minimum deviation, which may be rotated through a relatively considerable angle without bringing about a very perceptible increase in deviation.



The accompanying diagram is a section of the objective taken along a diameter. The focal length is eighteen times the aperture. If specially required, the aperture can be made equal to one-fifteenth of the focal length in the case of sizes up to 8 or 10 inches aperture. A relatively large focal length is, however, most to be recommended.

The lens L_1 which is placed first to receive the parallel rays

is made of Schott's baryta light flint glass 0·543, whose refractive index for D ray is about 1·564.

The negative lens L_2 is made of Schott's new boro-silicate flint glass, which is a variety of their 0·164. Its refractive index for D is 1·547.

The glass of which the third lens L_3 is made is a sort of light silicate crown (Schott's 0·374), which differs from ordinary hard crown in having a lower dispersive power and a somewhat different rationality. Its index of refraction for D is about 1·511.

The separation between the negative lens L_2 and the positive lens L_3 is designed for the purpose of correcting the spherical aberration perfectly for all colours.

The contiguous second and third surfaces r_2 and r_3 are curved to exactly the same radius; also the fourth and fifth surfaces r_4 and r_5 are curved to the same radius. The last surface r_6 is concave, and curved to a radius equal to nearly twice the focal length. There are thus three hollow surfaces whose figuring can be directly tested by reflected light, while each of the other three convex surfaces can be tested for figuring in an indirect manner. For instance, if all three concave surfaces are approved, and faults at the focus are found to exist which must be caused by defective figuring in one or more of the convex surfaces, then they can be tested in the following manner:—

If the faults at the focus are due to defective figuring in the second surface, those faults will more or less totally disappear on introducing some liquid having a refractive index approximately equal to that of glass between the two surfaces r_2 and r_3. If it is desired to test the fifth surface, then the brass ring separating L_2 from L_3 is taken out and put between the second and third surfaces, while L_2 and L_3 are brought close together. The objective being first tested in this state with its surfaces dry and the faults at the focus noted, then the refracting liquid may be introduced between the fourth and fifth surfaces, when, if the fifth surface is faulty in figure, the faults at the focus will more or less disappear. But if both the second and fifth surfaces are not found to be faulty by this method, then the conclusion is that the first surface r_1 is really at fault. Thus, all surfaces may be easily tested either directly or indirectly, and the whereabouts of small errors of figuring revealed, which are too fine to be appreciated by the use of spherometers or other mechanical tests. Thus no time need be lost in refiguring the wrong surfaces.

The baryta light flint and light silicate crown glasses used for the two exterior lenses are as hard and durable as ordinary crown glass, and if anything more colourless and transparent.

The boro-silicate flint glass used for the negative lens is of quite a different type from that used by Professor Hastings for his patented doublet. Indeed, this flint is the only available

glass which can be used for apochromatic objectives, and can be turned out in large-sized discs. Its mechanical hardness is very great—greater indeed than that of hard crown. It is beautifully transparent to all the brighter rays of the spectrum, but begins to absorb the violet rays after the G line is passed. This characteristic imparts a lemon yellow colour to a lens when of two inches thick or over, but it is scarcely noticeable in the case of lenses of moderate sizes.

In a town atmosphere, where sulphuretted hydrogen or sulphuric acid abounds, it would not be safe to use this flint for an exterior lens; but when enclosed between the two positive lenses, as in this objective, we have no reason for expecting it to be any less permanent in its polish than the dense flint glass which has hitherto been used for double object glasses of the usual construction. Or even supposing a slight amount of tarnishing of its surfaces did take place after many years, as is the case with the flint glasses hitherto used for telescope object glasses and prisms, it may yet be asked whether the transparency or light-transmitting power of the objective would be in any degree impaired. We know well enough that a tarnished optical surface does not look so brilliant *by reflected light*. It may seem a somewhat startling statement to make, but nevertheless it is a fact, that certain flint glasses which we have experimented with by local tarnishing have been found to transmit actually more light where tarnished than where the surfaces had had their original polish preserved, and in no case has it ever been found that tarnish in any perceptible degree interfered with transparency.* We have yet to make some further experiments in this direction, and I hope at some future time to throw the proofs of this statement on the screen for your inspection. Those who use ordinary refractors may congratulate themselves on the fact that the light-gathering power of their objectives slightly increases with age, provided the surfaces are kept clean. However, leaving that interesting point for the present, I may say that enough experiments, extending over about a year and a half, have been made with this new glass to fully satisfy Messrs. T. Cooke & Sons of its lasting properties, and to warrant them in guaranteeing the permanency of this objective.

I will here give a table setting forth the optical properties of the three glasses, and also showing how very closely all the rays of the spectrum can be refracted to one focus.

* Of course this statement is not intended to apply to the case of a surface which is actually corroded, so as to appear at all *grey* or *milky* by reflected light.

1	2	3	4	5	6
Region of Spectrum.	Partial Dispersions or $\Delta\mu_1$ for Glass o·543.	Partial Dispersions or $\Delta\mu_2$ for Glass o·374.	Combined Partial Dispersions or $\Delta\mu_1+\Delta\mu_2$ for Glasses o·543 and o·374.	Proportional Dispersions C to F being Unity for Glasses o·543+o·374.	Proportional Dispersions for Boro-silicate Flint o·658.
C to F	·01115	·00844	·01959	1·0000	1·0000
...	(1·0000)	(1·0000)			
A to C	·00374	·00296	·00670	·3420	·3425
...	(0·3354)	(0·3507)			
D to F	·00790	·00593	·01383	·7059	·7052
...	(0·7085)	(0·7026)			
E to F*	·00369	·00274	·00643	·3282	·3278
...	(0·3309)	(0·3247)			
F to G (Hγ)	·00650	·00479	·01129	·5763	·5767
...	(0·5830)	(0·5675)			
F to H_1*	·01322	·00976	·02298	1·1730	1·1745
...	(1·1857)	(1·1564)			

This table is calculated on the supposition that

$$\frac{1}{\rho_1}=\frac{1}{\rho_3},$$

where $\frac{1}{\rho_1}$ = the sum of the reciprocals of the radii of the first lens and $\frac{1}{\rho_3}$ = the sum of the reciprocals of the radii of the third lens. This pretty well represents an average case, and with the present meltings of glass gives the most perfect colour correction. The curves may of course be varied within certain limits in order to compensate for variations in the optical qualities of the glasses.

But under the conditions above defined it is evident to those conversant with optics that the partial dispersions for these two positive lenses combined, for any given region of the spectrum, is obtained by simply adding together their respective dispersions for that region of the spectrum.

In column 2 are given the partial dispersions of baryta light flint glass o·543 for the different regions of the spectrum indicated in column 1.

In column 3 are given the corresponding partial dispersions for the light silicate crown glass o·374. The figures in brackets beneath these in columns 2 and 3 indicate the relative partial dispersions for each region of the spectrum when the dispersion from C to F for each glass is taken as unity.

* Figures relating to spectral regions E to F and F to H_1 are calculated from Messrs. Schott's measurements by means of Cauchy's dispersion formula.

In column 4 are given the sums of the partial dispersions for each region of the spectrum, obtained by simply adding together the partial dispersions for 0·543 and 0·374 respectively for each region of the spectrum indicated in column 1.

In column 5 the combined dispersion for the two positive lenses for the region C to F is taken as unity, and the relative proportions of the combined dispersions for the other regions of the spectrum are expressed in fractional parts of the combined dispersion from C to F. Finally, in column 6 are given the corresponding proportional dispersions in the same sense as in column 5 for the boro-silicate flint glass 0·658. I need scarcely explain that the perfection of the achromatism of the triple combination is made manifest by the remarkably close agreement between the proportional dispersions for the two positive lenses combined, on the one hand, and the proportional dispersions for the negative lens on the other hand.

The rationality of dispersion, as it is generally termed, is in remarkably close agreement.

These figures do not pretend to accuracy in the fourth decimal place, but I would point out that an error of ·0010 in any one of these figures would, in the case of a 6-inch O.G. of 108 inches focal length, correspond to a longitudinal aberration of only ·02 inch; an amount which, I believe, the most delicate test could scarcely reveal, owing to the cone of rays close to focus merging in such a remarkable manner into the cylindrical form.

Owing to the expensive nature of experiments of this sort, the first objectives actually made on this principle and finished were of the moderate aperture of $3\frac{1}{2}$ inches; but these were found so successful as to leave no doubt about much larger sizes being practicable should the glass be forthcoming. However, a recent visit to Dr. Schott and Professor Abbe at Jena has quite set at rest any doubts as to the possibility of turning out discs of considerable sizes, many discs of moderate dimensions, up to 9 inches, and possibly 12 inches diameter, being already available. Dr. Schott is of opinion that only actual experience with future meltings will determine up to what sizes it will be possible to manufacture perfect discs.

It is easily seen from the diagram that the total thickness of glass in this new objective is a trifle over $1\frac{1}{2}$ times the thickness of glass used in an ordinary double objective of the same aperture, and it might be thought that a serious loss of light might result therefrom in large sizes. I have recently made some experiments upon the transparency of some blocks from 4 to 5 inches thick of the three glasses used in the objective, and have been pleased to find that a thickness of 5 inches of the baryta light flint absorbed only 40 per cent. of candle light; a thickness of $4\frac{7}{8}$ inches of boro-silicate flint absorbed 27 per cent. of candle light (though doubtless more of daylight); while a

thickness of $5\frac{1}{16}$ inches of the light silicate crown absorbs only 20 per cent. of candle light.

These figures must be regarded as preliminary. I intend to check the results and present them in a more accurate and digested form on a future occasion. But as far as they go these results are surprising as showing what an improvement has taken place in the transparency of glasses (a few blocks of ordinary crown and flint glasses were also tried and found nearly as transparent as the block of 0·374) within the last few years, when thicknesses of four inches only were generally found to absorb as much as one half of the light.

Thus this triple objective might be made in very large sizes, 2 feet aperture or so, before the loss of light due to thickness would become so great as to put it on an equality as regards light-gathering power with a Newtonian reflector of average condition and similar aperture.

Buckingham Works, York.

Brilliant Detonating Fireball of 1894 *January* 25.

By W. F. Denning.

A very murky condition of sky, with occasional rain, appears to have prevailed over a considerable part of England on the night of 1894 January 25, and the only celestial objects visible were *Jupiter* and two or three of the brighter stars shining very dimly through the clouds. At about $10^h\ 1^m$, in the Midland Counties, the dark atmosphere was instantaneously illuminated with a light perfectly dazzling in its intensity, and people who noticed it thought for a moment that the full Moon had suddenly come into view. On glancing upwards, however, they immediately detected the real cause in the form of a large pear-shaped fireball rolling across the sky from the direction (as observed at many places) of N.W. to S.E., and scattering behind it a bright tail of sparks. Those who obtained the most complete view of the object describe it as small at first, like an ordinary shooting star, but, after traversing about one-third of its course, it appears to have suddenly burst out into a startling size and brightness, and afterwards divided into two parts. As it disappeared the section of its track following the nucleus was beaded with fragments decreasing in size from the foremost. The colour of the latter was variously described as blue and green, and several observers compare it with the electric light; the tail and hinder parts of the nucleus appear to have been yellow merging into red. From one to four minutes after the meteor had disappeared alarming detonations were heard at Worcester, Droitwich, Birmingham, Alvechurch, Malvern, Ross, Stroud, Cheltenham, and numerous other places in the same

district. Houses were shaken, windows and furniture were rattled violently, and there was a perceptible vibration which many people quite naturally mistook for an earthquake shock.

I have collected about forty-five descriptions of the fireball, and though the majority of these are merely of a popular character, containing few details useful for scientific purposes, there are several by astronomical observers, and these enable a satisfactory path to be derived. It may be interesting to quote from some of the best accounts:—

Clapham, near Lancaster.—Very brilliant meteor seen at $10^h\ 5^m$, January 25. The sky was covered with light clouds, so that only the larger stars could be seen through the film. When first observed the meteor was near the *Pleiades*, its course being close to the belt of *Orion*, and it disappeared in the neighbourhood of η *Canis Majoris*. Duration six seconds.—*T. E. Clapham.*

King's Heath, Birmingham.—At $10^h\ 3^m$, the sky being so hazy that only *Jupiter* and one or two stars were visible, a brilliant light suddenly appeared in the N.W. sky. On looking up a fireball of extraordinary brilliancy was perceived. Its motion was remarkably slow, and a train of great length followed in its wake. It traversed an arc of 120°, passing between *Jupiter* and the *Pleiades* and breaking up near *Rigel*. The nucleus was a brilliant bluish white colour, and its motion was uneven, as though the body encountered impediments in its flight through the atmosphere. The meteor sent out a distinct hissing sound during a considerable part of its passage. The end point was very fairly determined, for the moment after the meteor had expired *Rigel* appeared to view, and gave the transient impression of being a portion of the nucleus that had suddenly become stationary. The duration of the whole apparition was twelve seconds. About three minutes after the meteor burst the report came: it resembled the "boom" of distant artillery. The report was distinctly a double one, followed by a dull reverberation that resounded from all parts of the sky.—*D. E. Packer.*

Edgbaston, Birmingham.—At $10^h\ 1^m$ a detonating meteor equal in size to a half-moon was seen. The sky was overcast, only the planet *Jupiter* being dimly visible, but the meteor illuminated the country like bright moonlight. At the end of its flight the nucleus burst, showering down fragments. An audible sound was heard at $10^h\ 4^m\ 5^s$, resembling the subdued report from a piece of ordnance. The colour of the forward part of the nucleus was electric blue, the rest red; duration of flight 12 seconds. Path from Az. 15° W. of N., alt. 20°, to Az. 30° W. of S., alt. 25°.—*W. H. Wood.*

Sunderland.—Bright meteor, $= 4$, and apparently directed from the place of that planet, disappeared behind a house at a

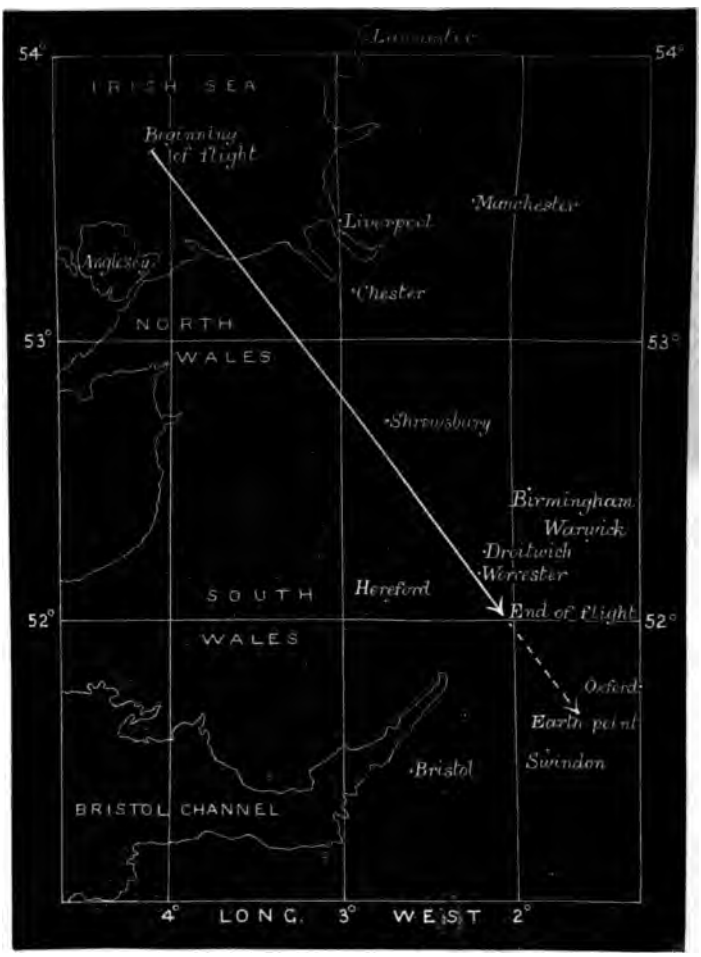
position occupied on February 2 at $9^h\ 27^m$ by $75° - 25°$. Course seen about 7°. Very slow, 1·2 second; colour green. Seen imperfectly through clouds.—*T. W. Backhouse.*

Bristol.—At $10^h\ 1^m$ a sudden and great brightening of the sky caused the observer to look upward, and the fireball was well seen during the last ten degrees of its course. The position was determined as from $242° + 59°$ to $229° + 53°$, and this may be considered pretty correct as to direction, though to include the whole visible path the line of flight must be extended back to about η *Cephei*. The place of the end-point corresponds approximately with Az. 26° E. of N., alt. 20°, and from several careful descriptions by other observers at Bristol the beginning occurred at Az. 22° W. of N., alt. 26°. Ten degrees from the point of its extinction the fireball consisted of a double nucleus, the foremost of the two parts being largest and brightest. Near the end these subdivided and formed a string of particles, when the whole phenomenon collapsed, and the sky resumed its previous darkness. The estimated duration was five seconds from the time of the first outburst of light, but the 10° of the observed path occupied less than two seconds.—*W. F. D.*

The other accounts need not be particularly referred to, as for the most part they simply describe the astonishing brilliancy of the meteor and its rough position. An observer at Henbury says it made a hissing noise as it passed, thus confirming Mr. Packer's impression.

As to the detonation that followed the meteor's disruption, this appears to have varied according to locality. Mr. W. H. Lloyd, of Stroud, describes it as a series of explosions (apparently from the N.E.) which sounded like a number of fieldpieces fired in rapid succession, followed by a volley of musketry. Mr. J. T. Southall, of Ross, Hereford, says a loud rumbling noise like an explosion was heard. It lasted two or three seconds, and two slight shocks, supposed to be due to an earthquake, were experienced. At Worcester the path of the meteor was from N.W., and shortly after its disappearance three detonations were heard, the last being of exceptional violence, shaking buildings and causing the earth to vibrate. At Droitwich it was supposed the Evesham Gas Works, twelve miles distant S.E., had blown up. At Alvechurch a detonation was heard similar to a clap of thunder. At Malvern, at $10^h\ 3^m$, a meteor of extraordinary size and brilliancy came from a N.W. direction, and three minutes after its disappearance a heavy rumbling noise was heard, immediately followed by the sound of a tremendous explosion. Mr. W. E. Clarke, of Elkstone (between Cheltenham and Cirencester), says he heard several explosions, and these seemed to come right from the opposite direction to the meteor's flight, and about ten or fifteen seconds after its disappearance. He refers to a peculiar "whirring" noise which followed the detonations, and says the nearest resemblance to it he can suggest is "the sound

made by rapidly swinging round and round a piece of tin attached to the end of a string."



Path of Detonating Fireball, 1894 January, $25^d\ 10^h\ 1^m$.

I have compared the various observations of the apparent path, and find there is a tolerably good agreement amongst them. The following are the resulting positions and heights:—

Observed beginning of flight over a point in lat. 53° 42′ N., long. 4° 7′ W. (24 miles N.N.E. of Amlwch, Anglesey); height 89 miles.

Observed ending of flight over lat. 52° 2′ N., long. 2° 5′ W. (Ashchurch, Tewkesbury); height 16 miles.

Earth point in lat. 51° 42′ N., long. 1° 42′ W. (Lechlade, on the eastern border of Gloucestershire).

Real length of observed path = 160 miles.

Duration of flight (mean of twelve estimates) = 9 seconds.

Velocity 18 miles per second.

Radiant point 331° + 55°, near ϵ *Cephei*.

The meteor passed almost vertically over Shrewsbury and Worcester, at elevations of 45 and 22 miles respectively.

The observed beginning is that noted by Mr. Clapham, whose position was 22 miles N.E. of Lancaster. Possibly the fireball may have acquired visible incandescence much earlier than this in its flight, and when it was passing over the Isle of Man, but we have no positive evidence on this point. Nearly all the observations cluster round the counties of Warwick, Worcester, Hereford, and Gloucester, and there is a singular lack of accounts from North Wales and the northern parts of England. The cloudy state of the sky at the time is no doubt in a great measure responsible for this. There is, it is true, one report from Mold, North Wales, where the meteor appears to have looked larger than the Moon, but no particulars are given as to the path.

The height at end is well indicated by the King's Heath (Birmingham) and Bristol observation. It agrees also with the interval between the explosion and detonation, as recorded at Birmingham and some other places. Mr. Packer, at King's Heath, puts the interval at 3 minutes, while Mr. Wood, at Birmingham, estimated it as 3 minutes 4 seconds. The meteor was 36 miles distant from Birmingham at the end point, and sound, travelling at the rate of 1,090 feet per second, would occupy 3 minutes in traversing 37 miles. The agreement is not so precise when the same comparison is applied to certain other stations, but it must be remembered that the time intervals were in nearly every case little better than mere guesses, and not well-determined periods. Moreover, the detonation may not have been caused by the disruption of the meteor precisely at the place of its extinction, for disintegration had been obviously going on some time before. Several of the accounts would appear to suggest that one of the explosions must have occurred when the meteoric *débris* had gone a few miles beyond the place of its disappearance in a prominently luminous state.

It is evident that distance had a great effect upon the apparent brightness of the object. At Sunderland the observer estimated it as equal to *Jupiter*, but his position was about 175 miles from the section of the meteor's path, S.E. of Shrewsbury, which he observed. At Clapham, Lancaster, the distance from the meteor was also considerable, varying from 120 to 157 miles, and here the light was thought to equal *Venus*. But at Worcester, where the minimum distance was only 22 miles, the meteor illuminated the sky with an effect exceeding that of the full Moon, and it was compared to that of the great electric search-light by several observers.

The duration of the meteor's flight was variously estimated at from 1 or 2 seconds to 1 or 2 minutes. A mean of twelve of the most reliable accounts gives 9 seconds, and from this I derive the velocity as 18 miles per second. Atmospheric resistance no doubt had the effect of considerably moderating the native speed of the meteor.

The radiant point at 331° + 55° near ϵ *Cephei* is rather a novel one for the season, and I believe the only January shower of Cepheids hitherto observed is that seen at 329° + 60°, 1886 January 4–8, by the writer at Bristol. In the summer and autumnal months there are many radiants in this region of *Cepheus*, and the position represents one of the apparently long-enduring, fixed showers which are so difficult of explanation (see *Monthly Notices*, vol. l. pp. 416 and 467).

The great detonating fireball seen in the north of England on the morning of 1879 February 24 had a radiant approximately determined at 310°+55°, and suspiciously near that of the similar fireball of January 25 last.

It is, perhaps, a little questionable whether large fireballs of the detonating class are always indicative of ordinary meteor showers, as they often appear in an isolated manner and are frequently directed from radiants situated in the vicinity of the horizon and in the western half of the sky. Slowness of motion is also a characteristic feature of these bodies. After seeing one of them an observer may watch the heavens during the remaining part of the night and note many meteors without detecting one from the fireball radiant. This has sometimes been my own experience, and there seems little reason to doubt the comparative exclusiveness of such phenomena. But of course if observations were undertaken on a wider basis, and many observers participated in them, the solitary nature of these bodies might not be confirmed. It is one of those features on which we cannot speak with certainty owing to the inadequacy of past observation. But in whatever light we regard these brilliant slow-moving fireballs it is certain they form the most interesting and attractive type of meteoric apparitions.

Bristol:
1894 *February* 4.

Erratum in Col. Markwick's paper. (*"Monthly Notices," vol. liv. No.* 3.)

In the diagram on page 139 of the "Light Curve of W Sagittarii" the numbers denoting the brightness should be shifted upwards one line, so that the top line reads 4·8 and the lowest line 5·8.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. APRIL 13, 1894. No. 6

E. B. KNOBEL, Esq., Vice-President, in the Chair.

Lyndon Bolton, B.A., Patent Office, Chancery Lane, W.C.;
F. W. Dyson, M.A., Royal Observatory, Greenwich, S.E.;
G. P. Jenkins, Esq., Llangefni, Anglesea, North Wales;
W. Redfern Kelly, Mem. Inst. C.E., Dalriada, Malone Park, Belfast;

were balloted for and duly elected Fellows of the Society.

The following were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

The Rev. Thomas Windmill Claridge, M.A., Tamworth, Staffordshire (proposed by Rev. Thomas Jones);
David Goudie Simpson, 199 Camberwell Grove, Denmark Hill, S.E. (proposed by Gainsford Bruce);
Rev. Ernest Harrison Smith, M.A., R.N., Chaplain and Naval Instructor H.M.S. "Tourmaline," North American and West Indian Station (proposed by Bertram Bennett);
Sir John Benjamin Stone, K.B., The Grange, Erdington, near Birmingham (proposed by W. Shackleton).

Seventy-one presents were announced as having been received since the last meeting of the Society, including, amongst others—

Kiel Observatory publications, no. ix. (E. Lamp, Comet 1891, I.; H. Kreutz, Comet 1873, V., &c.), presented by the Observatory. L. S. Fabry, Étude sur la probabilité des comètes hyperboliques et l'Origine des Comètes, presented by the author; Barlow and Bryan, Elementary Mathematical Astronomy, third edition; and Briggs and Bryan, Co-ordinate Geometry, part 1, presented by the editor.

Remarks on the Best Methods of Determining the Positions of the Planets by Observation. By David Gill, LL.D., F.R.S., Her Majesty's Astronomer at the Cape of Good Hope.

In the *Astronomical Journal*, No. 311 (1894 February 10), Professor Simon Newcomb has called attention to the great accuracy attainable in heliometer measures of the distance and position-angle of planets from selected comparison stars, and of the precision in the resulting places of the planet which may be reached when the comparison stars have been observed on the meridian at many different observatories, and specially when these stars have also been connected by triangulation.

The instance quoted by Professor Newcomb is afforded by the heliometer observations of *Mars* at Ascension in 1877, by which a then unexplained apparent periodic inequality in the motion of *Mars* was detected. This apparent inequality has since been shown to have arisen from an inadvertent error in the computation of the nutation in the special ephemeris of *Mars* supplied by the *Nautical Almanac* office.

Thus, to use Professor Newcomb's words, "a minute inequality, which would never have been noticed in even the best meridian observations, was brought to light, and mapped in a diagram so as to be unmistakable."

Striking as this result may be, the accuracy of the *Mars* observations is very inferior to that realised in the observations of the minor planet *Victoria* in 1889; and, pending the publication of the complete work now in the press, it may not be out of place to give the following illustrations.

It should be mentioned that the exactness of the observations has been the chief cause in the delay of publication. The results of their preliminary discussion (orally communicated to the Society at its meeting on 1893 March 10) showed, on closer examination, that the accuracy of the existing Solar Tables and the employment of seven-figure logarithms in the computation of the ephemeris from the elements were insufficient to respond to the accuracy of the observations.

With great kindness Professor Tietjen undertook the labour of computing a new ephemeris, with special perturbations and the use of eight-figure logarithms, at the office of the *Berliner Jahrbuch*. This has also involved a complete re-computation of the whole work, and the introduction of many refinements hardly applicable in the first discussion. The observations are now represented by residuals less by one-half than those previously found. This latter remark, of course, applies chiefly to the absolute errors of the planet in right ascension and declination, and not to the separate values of the parallax, because in the latter case the comparative roughness of the original ephemeris is to a great extent eliminated by the nearly simultaneous epochs of the observations in opposite hemispheres from which the parallax is deduced.

A "Set" of observations is defined as all the observations of the same class made by the same observer at the same sitting.

The various sets of observations are combined in "Groups," following each other in the order of date. The limits of these groups are so fixed as to afford in general a strong determination of the planet's right ascension, declination, and parallax from each group, the only exception to this rule being Group I., because the only observations before June 15 were a single set at the Cape on June 10, and a single set at Göttingen on June 11, both consisting only of measures of distance of the planet from the opposite stars κ and μ; and it seemed undesirable to unduly extend the limits of Group II. to include these comparatively isolated observations. Group I. thus contains only two sets of observations, and these afford a determination of the parallax, but no data to distinguish between the tabular errors in right ascension and declination.

The observations of each group are reduced to a common epoch; and in the following table are given the actual corrections, $\Delta\alpha \cos\delta$ and $\Delta\delta$, applicable to the new ephemeris, which result directly from the observations.

Group.	Period covered by the observations.	Epoch to which each group is reduced.	$\Delta\alpha \cos\delta$ O−C arc.	Weight.	$\Delta\delta$ O−C	Weight.	No. of sets.	No. of stars.	Tabular effect of Lunar perturbation. $\Delta\alpha \cos\delta$	Tabular effect of Lunar perturbation. $\Delta\delta$
II.	June 15–18	June 17·0	−0″·139	11·6	+0″·686	12·7	12	2	+2·49	−1″·22
III.	19–25	22·0	− ·153	17·8	+ ·683	19·5	22	2	+7·28	+0·74
IV.	June 26 July 2	29·0	− ·207	13·5	+ ·755	35·1	24	10	+0·98	+2·20
V.	July 3–8	July 6·0	− ·162	13·7	+ ·743	16·0	11	7	−7·33	−0·37
VI.	9–12	11·0	− ·237	12·7	+ ·746	13·9	14	3	−3·10	−2·17
VII.	15–19	18·0	− ·228	22·8	+ ·791	22·7	10	3	+7·49	+0·04
VIII.	20–22	21·5	− ·173	19·6	+ ·808	11·8	7	1	+6·93	+1·76
IX.	23–24	24·0	− ·235	20·4	+ ·873	25·1	14	4	+3·98	+2·45
X.	25–27	26·0	− ·257	17·4	+ ·832	14·3	4	1	+0·76	+2 52
XI.	July 28 Aug. 2	Aug. 1·0	− ·343	42·2	+ ·821	38 6	31	8	−1·12	+0·36
XII.	Aug. 4–9	7·0	− ·442	22·4	+ ·746	21·4	7	3	−3·15	−2·08
XIII.	10–16	13·0	− ·302	23·3	+ ·713	24·1	22	2	+6·13	−0·67
XIV.	17–21	19·0	− ·337	16·8	+ ·588	21·9	16	6	+4·84	+1·85
XV.	22–26	24·0	− ·394	13·2	+ ·505	15·4	8	1	−2·13	+1·81

These errors cannot be expressed with sufficient accuracy in terms of the elements of the planet, because of small errors in the solar tables, whence the data for the Sun's elements were derived (see report of the Cape Observatory, *Monthly Notices*, 1894 February), and also because of errors in the perturbations which may be quite sensible. But apart from the error of the lunar perturbation of the Earth, the errors of the tabular place of the planet can be developed in terms of the distance and powers of the time with all requisite accuracy.

Thus we put

$$\Delta\alpha \cos\delta = \frac{1}{\Delta}\alpha + \frac{t}{10\Delta}\beta + \frac{t^2}{100\Delta}\gamma + \frac{t^3}{10{,}000\Delta}\delta + \frac{t^4}{100{,}000\Delta} + l\mu$$

$$\Delta\delta = \frac{1}{\Delta}\alpha' + \frac{t}{10\Delta}\beta' + \frac{t^2}{100\Delta}\gamma' + \frac{t^3}{10{,}000\Delta}\delta' + \frac{t^4}{100{,}000\Delta} + l\mu$$

where Δ is the distance of the planet from the Earth (mean distance of Sun from Earth being $=1$); t, the time, expressed in days, from July $18^{d}\cdot0$; α, β, γ, &c., constants to be determined; l, the effect of the tabular lunar perturbation of the Earth on the tabular places of the planet, as given in the right-hand margin of the table. (These quantities are identical with those used for the dates in question in the computation of the ephemeris.) Consequently, if L′ be the tabular value of the constant of the lunar perturbation of the Earth, the true value of that constant will be

$$L'(1+\mu).$$

Forming normals of the above type, having regard to the weights of the equations, and solving them, we obtain

A. Including all terms ... ... $\mu = +0\cdot00786$
B. Excluding terms depending on t^4 ... $\mu = +\cdot00801$
C. „ „ t^3 and t^4... $\mu = +\cdot00647$

Substituting these and the values of the other unknown quantities, there result from the three solutions the following residuals in the sense O—C:

	A		B		C	
	$\Delta\alpha\cos\delta$.	$\Delta\delta$	$\Delta\alpha\cos\delta$.	$\Delta\delta$	$\Delta\alpha\cos\delta$.	$\Delta\delta$
	″	″	″	″	″	″
II.	+0·029	+0·001	+0·045	+0·001	0·000	+0·082
III.	− ·030	− ·017	− ·033	− ·017	− ·033	+ ·004
IV.	− ·040	+ ·026	− ·048	+ ·026	− ·028	− ·003
V.	+ ·079	·000	+ ·075	·000	+ ·093	− ·050
VI.	− ·013	− ·010	− ·013	− ·010	+ ·008	− ·056
VII.	− ·050	− ·020	− ·047	− ·020	− ·023	− ·041
VIII.	+ ·032	− ·030	+ ·037	− ·030	+ ·050	− ·033
IX.	+ ·010	+ ·029	+ ·014	+ ·028	+ ·016	+ ·037
X.	+ ·028	− ·017	+ ·032	− ·017	+ ·024	·000
XI.	− ·002	+ ·002	− ·002	+ ·001	− ·024	+ ·034
XII.	− ·051	− ·011	− ·057	− ·011	− ·085	+ ·023
XIII.	+ ·035	+ ·015	+ ·025	+ ·015	+ ·020	+ ·036
XIV.	+ ·012	− ·016	+ ·016	− ·017	+ ·020	− ·028
XV.	− ·025	+ ·011	+ ·012	+ ·010	+ ·027	− ·058

The question as to whether the development of the ephemeris may be legitimately carried beyond the terms depending upon t^2 is still under discussion, but it seems probable that the term depending on t^3 should be included. This, however, does not materially affect the immediate object in view, which is to demonstrate that the *Victoria observations show as great an advance in accuracy on the Mars observations as the Mars observations do on the meridian observations.*

As a further test of accuracy the following are the separate resulting values of the mean Solar Parallax.

Values of the Mean Solar Parallax derived from the separate groups of the Victoria Observations.

Group.	From all observations combined.	Relative Weight.	Omitting the single (small) distances.	Relative Weight.
	"		"	
I.	8·751	0·9	8·751	0·9
II.	·758	15·3	·758	15·3
III.	·807	21·2	·831	15·0
IV.	·833	36·8	·829	36·8
V.	·764	9·9	·767	9·6
VI.	·842	21·3	·777	12·2
VII.	·793	30·7	·783	23·5
VIII.	·842	30·1	·827	15·6
IX.	·727	18·6	·727	18·6
X.	·817	15·7	·731	5·0
XI.	·804	57·3	·800	51·8
XII.	·802	32·0	·753	15·9
XIII.	·826	38·5	·820	26·2
XIV.	·799	28·0	·820	21·3
XV.	·729	12·8	·700	4·2
Mean	8″·804 prob. error ± 0″·0053		8″·794 prob. error ± 0″·0060	

The weights of the observations of single distances have been computed according to the residuals of the individual sets after several approximations. But in the measurement of short distances with the heliometer, small systematic corrections are required, of which the true origin is not yet fully explained, and the law expressing the corrections (though closely representing the observations) is but an empirical one; thus the weights of the short distances, from the point of view of possible small outstanding systematic error, are probably too great.

The equations resulting from double distances are practically free from all systematic error, provided only that the comparison stars are, on the whole, symmetrically situated with respect to the planet, and that the planet itself is indistinguish-

able from the average star of comparison. Both these conditions are realised in the case of *Victoria*.

If the above results are combined with their nominal weights we have from the *Victoria* observations

$$\pi = 8''{\cdot}800,$$

which is equivalent to giving half weight to the single observations, and the probable error is then

$$\pm 0''{\cdot}0057.$$

In the observations of *Sappho* the star places were not connected by triangulation; the parallax has therefore been deduced solely from observations where the angular distance of the planet has been measured from the same pair of comparison stars, on opposite sides of the planet, at observatories in opposite hemispheres. The results are thus independent of the errors of the star places, and practically independent of any other systematic errors.

Values of the Mean Solar Parallax derived from the separate groups of the Sappho Observations.

	Group.	π	Weight.
Sept. 18–22	I.	8″·755	9·91
23–27	II.	·781	13·47
Sept. 28 Oct. 2	III.	·794	12·43
Oct. 10–13	V.	·815	8 61
14–18	VI.	·840	9·43
19–27	VII.	·805	14·21

Group IV., consisting of observations October 3–6, contains only the observations from the stars $t\,x$ available for our purpose. Of these, the star t is a double star (mags. 8·2 and 9·3; $s = 0''{\cdot}9$, $p = 175°$), and it seems doubtful if it was similarly observed in both hemispheres. It is considered safer to reject the observations of Group IV.

The mean result is then

$$\pi = 8''{\cdot}796 \text{ with prob. error } \pm 0''{\cdot}007.$$

If, instead of combining the observations in groups, the parallax is derived from the twenty-two independent determinations, in which a different pair of comparison stars is used for each determination, we get

$$\pi = 8''{\cdot}796 \text{ with prob. error } \pm 0''{\cdot}014.$$

So that some considerable compensation of error is apparently

produced by the combination in groups. We may therefore adopt

From the *Victoria* observations,	$\pi = 8''.800$	prob. error $\pm 0''.006$
„ *Sappho* „	8·796	„ ± ·012
The mean, having regard to weight,	8·799	„ $\pm 0''.005$

and it is very improbable that this value is one-hundredth part of a second of arc in error.

This value of the solar parallax, combined with Newcomb's value of the velocity of light (299,860 km.), and Clarke's value of the Earth's equatorial radius (6,378·2 km.), gives for the constant of aberration

$$20''.48.$$

Chandler, in his investigation of the aberration constant from existing data, having regard to its modification by his discovery of the change of latitude, finds

$$20''.50$$

for the aberration constant.

On the other hand, Loewy, by his own method, which is independent of the latitude, finds a close approximation to $20''.45$; and Preston, in his discussion of the recent "Talcott" observations for change of latitude, an even smaller value. Loewy's results are independent of the change of latitude, but are seriously affected in their accidental errors (possibly to some extent systematically also) by flexure of the plane mirrors of the equatorial coudé—an instrument not so well suited as one of direct vision for the application of Loewy's beautiful method. The fine series of "Talcott" observations discussed by Preston * is wanting in early morning as well as evening observations; otherwise the result would have had a much greater weight.

Comstock's determination of the aberration constant by a modification of Loewy's method † gives $20''.494 \pm 0''.017$. Of all these recent values, $20''.48$ seems the most probable mean; at least, one cannot conclude that the value of the solar parallax resulting from the *Victoria* and *Sappho* observations is at variance with our existing determinations of the aberration constant and the velocity of light.

Le Verrier's equations for rigorously computing the lunar perturbation of the Earth may be written in the form

$$dr = \frac{m'}{m+m'} \cdot \frac{\pi}{\sin Q} \cdot \cos s' \cdot \cos(\nu' - \odot) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$r \cdot d\nu = \frac{m'}{m+m'} \cdot \frac{\pi}{\sin Q} \cdot \cos s' \cdot \sin(\nu' - \odot) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$r \cdot ds = \frac{m'}{m+m'} \cdot \frac{\pi}{\sin Q} \cdot \sin s' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

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* *U.S. Coast and Geodetic Survey Bulletin*, No. 28.

† *Astronomical Journal*, vol. xi. page 161.

where

Q is the Moon's horizontal parallax at the epoch.

s' „ „ true latitude at the epoch.

v' „ „ „ longitude at the epoch.

r „ Earth's radius vector.

π „ mean solar parallax.

$\odot$ „ Sun's true longitude.

m and m' are the masses of the Earth and Moon.

These expressions are perfectly rigorous, but they may be developed in various ways for computing the lunar perturbation by the use of tables.

To avoid the confusion which may arise from the employment of the principal term of any development of the so-called lunar equation, we shall define the expression

$$L' = \frac{m'}{m+m'} \cdot \frac{\pi}{\sin Q_0} \quad \ldots\ldots\ldots \quad (4)$$

as "the tabular constant of the lunar perturbation of the Earth," where Q_0 is the tabular value of the mean horizontal parallax of the Moon, and the other expressions on the right-hand side of the equation are the tabular values of m' and π.

The new ephemeris of *Victoria* was first computed so that the tabular place of the planet was referred to the centre of gravity of the Earth and Moon; dr, $r \cdot dv$, and $r \cdot ds$ were then rigorously computed for every day by equations (1), (2), and (3), and the resulting values were transformed into $\Delta\alpha$ and $\Delta\delta$ so as to refer the ephemeris to the centre of the Earth.

Since the tabular values of the true radii vectores of the Earth and Moon may be regarded as exact (they are certainly so within $\frac{1}{5000}$th part of each), the true values of dr, $r \cdot dv$, and $r.ds$, computed from the tabular values, may always be expressed by

$$(1+\mu)\, dr, \quad (1+\mu)\, r \cdot dv, \quad (1+\mu)\, r \cdot ds,$$

and the constant of the lunar perturbation of the Earth will be

$$L = L'(1+\mu). \quad \ldots\ldots\ldots \quad (5)$$

The tabular values employed in the new ephemeris were

$$\pi = 8''{\cdot}880; \; m' = \frac{1}{83}, \text{ or } \frac{m'}{m+m'} = \frac{1}{84}; \; Q_0 = 3423''{\cdot}0.$$

Substituting these values in equation (4) we obtain

$$L' = 6''{\cdot}3705.$$

Hence, by equation (5),

	Solution A.	Solution B.	Solution C.
$L = L'(1+\mu) =$	$6''{\cdot}421$	$6''{\cdot}421$	$6''{\cdot}412$.

Thus the resulting constant of the lunar perturbation of the Earth will be

$$6''{\cdot}42$$

if terms higher than the square of the time are employed in determining the errors of the ephemeris, or

$$6''{\cdot}41$$

if the same development is limited to the square of the time.

Pending the definitive discussion of this point, and adopting

$$L = 6''{\cdot}42$$

we have

$$\frac{m'}{m+m'} = \frac{L \sin Q_0}{\pi} \quad \ldots\ldots\ldots \quad (6)$$

where all the quantities should be true values.

Now Q_0 is probably accurate within $\frac{1}{500}$th part; π, as determined from the preceding observations, nearly within $\frac{1}{1000}$th part; and L (not yet definitively fixed), about $\frac{1}{600}$th part.

Substituting the known values of Q_0, and the above-mentioned values of L and π, we have, from equation (6),

$$\frac{m'}{m+m'} = \frac{1}{82{\cdot}59}$$

and

$$\text{the mass of the Moon} = \frac{1}{81{\cdot}59},$$

of which the probable error is about $\frac{1}{500}$th part.

In the face of such results it is evident that the time has arrived when astronomers should reconsider their methods of work. Future geometers are entitled to expect from the practical astronomer positions of the exterior planets five times more accurate than those at present available, and it may be well to consider the means by which such expectation can be best satisfied.

The keynote to the first advance towards this end will unquestionably be found in the spirit which has led to the success of the Astrophotographic Congress, and of the above-quoted observations of *Victoria*, viz., the international co-operation of all observatories that are occupied with astronomy of precision.

In the case of *Victoria*, twenty-two different meridian observatories co-operated in determining the places of the stars of comparison. The observatories at Göttingen, Yale, and the Cape, undertook the heliometer observation of the comparison stars, and heliometer observations of the planet itself were made

at Leipzig, Yale, Göttingen, Bamberg, and the Cape of Good Hope. Dr. Auwers also came from Berlin to take part in the observations at the Cape.

For determining important fundamental constants, like the solar parallax and the lunar equation, the highest available precision is requisite; hence the necessity for the large amount of concentrated activity on this special research. But in this case the highest precision is only required in the *relative* positions of the stars to each other and of the planet to the stars, but a like precision in the *absolute* place of the system of stars, regarded as a group, is not necessary.

The accuracy attainable in the *absolute* positions of planets is limited by the unavoidable systematic errors of our fundamental stars. At the present moment this uncertainty for any fundamental star amounts at least to $\pm 0''.3$; ultimately we may hope to reduce this uncertainty to $\pm 0''.1$. For determinations of the planet's position relative to surrounding stars, an accuracy of $\pm 0''.1$ will therefore probably suffice, and such precision can be attained for any epoch with perfect certainty by heliometer observations on three or four nights (that is to say, for the outer planets), provided that the absolute positions of the comparison stars are well enough known.

But by whatever process the position of the planet is referred to the comparison stars, and the relative position of these stars to each other is determined, their fundamental system of right ascension and declination must be ultimately referred to observations of the Sun. Thus, so far as our present knowledge and experience go, the basis of all our work must still be dependent on meridian observations with the transit circle or with some modification of that instrument in or out of the meridian.

One of the first steps, therefore, which it is desirable that astronomers should attentively reconsider is, How can the determination of absolute places of the fundamental stars be best improved? that is to say, by what method, or combination of methods, can we best arrive at the following problems?—

1. The determination of fundamental declinations, including, of course, the mean absolute latitude and the change of latitude of each fundamental observatory.

2. The elimination of the systematic error in observations of the Sun, which at present is due partly to personal error of the observer both in right ascension and declination, partly to the heat of the Sun's rays, which produce irregular expansion in the instrument employed.

3. The elimination of periodic errors in the right ascensions and declinations, or of errors depending on the brightness of the stars or on the direction of their apparent motion across the field of view.

In none of these respects does the present state of practical astronomy respond to the requirements of the problem. It is

true that every additional co-operating observatory (*especially if situated in the Southern Hemisphere*), every sound, independent method of observation, every systematic series of fundamental observations in the past or future, tends to strengthen the fundamental basis of our science.

But have these efforts in the past been thoroughly systematised so as to insure the best result from their combination? Has the work been so partitioned and systematised as to give the greatest efficiency for the labour expended? Have the instruments and observatories been so designed and employed as to afford, by their manner of construction, of employment, and of situation, the most perfect elimination of all sources of error? Have photographic and other automatic methods of registration yet been fully utilised in fundamental work?

To these and many kindred questions the answer must be in the negative.

If a new era of precision is to mark the progress of astronomy in the coming century, these questions should closely occupy the minds of astronomers in the immediate future, and the resulting suggestions be published, criticised, and made the subject of experiment.

In this way, preparation may be made for more perfect international co-operation, with better methods, better organisation, and more economy of labour in the common work.

Assuming that by some such means we shall arrive at the requisite precision in the places of the fundamental stars, it may be well to consider some of the further points raised by Professor Newcomb.

Before any satisfactory answer can be given as to the possibility of determining the position of *Mercury* and *Venus* by heliometer observations, it would be necessary to make special experiments. Having regard to the smallness of the disc of *Mercury*, the method of pointing by placing the image of the comparison star in the centre of gravity of the gibbous disc, or by bisecting the imaginary line joining the horns of the crescent, promises considerable accuracy. Such observations can only be secured in the exceptional conditions when the planet is within 2° of a star as bright as the 3rd or, in some circumstances, as the 4th magnitude. With *Venus*, especially in low latitudes, much fainter comparison stars might be similarly employed when the planet is not too near the Sun.

But it is unquestionably in observation of the outer planets that the greatest advance is possible. For *Mars*, *Jupiter*, and *Saturn*, the photographic method will probably prove far less satisfactory than heliometer observations; not that the difficulty suggested by Professor Newcomb (the fogging of the plates and the blotting out of the images of surrounding stars) may not be easily overcome, but because sharply-defined photographic images of such objects (i.e., whose limbs are capable of sharp bisection) cannot be obtained; at least, so far, this is the writer's

experience. The relative positions of *Jupiter's* satellites can, however, be determined with great accuracy by photographic methods. The minor planets, as well as *Uranus* and *Neptune*, may be photographically observed, probably with all desirable accuracy and with less labour than with the heliometer.

At present, however, there seems to exist no entirely satisfactory evidence on the latter subject, at least there is no published investigation in which the distortion of a photographic objective has been fully and satisfactorily worked out so as to show the law of distortion in terms of the distance from the centre of the plate, and also whether this distortion is the same in all radii. Bessel (*Königsberger Beobacht.* Abth. 5, p. iv.) found non-symmetric distortion in the field of the one object-glass which he fully investigated (see also *Encyclop. Britannica*, vol. xvi., Art. "Micrometer," p. 251), and some results of Jacoby's recent measurements of photographic plates appear to point to the existence of similar errors.

When this question has been fully worked out for any particular instrument (as may be comparatively easily done by photographic observation of the *Victoria* comparison stars), that instrument would probably be suitable for use, not only for the observation of *Uranus*, *Neptune*, and the minor planets, but for the triangulation or interconnection of the stars of comparison by micrometric methods.

Professor Newcomb's proposed photographic heliometer has claim to further study. It has the advantage of eliminating some of the errors due to optical distortion in the ordinary photographic method, and of personality in the observer's habit of pointing in the ordinary heliometer method. But it is very questionable if the photographic images, especially of planets, are capable of measurement with the same accuracy as the visual images. The proposed instrument has the same disadvantage as the ordinary heliometer, viz., that by one observation only one result is secured; whereas, by the ordinary photographic method the relative positions of all the available comparison stars on the plate are obtained; the proposed method also involves additional labour to that of ordinary heliometer observations, viz., the after labour of measuring the plates.

So far as can be judged from published photographs of test diagrams, there is a new form of photographic objective called the "Doppel-Anastigmate," which has been developed by Dr. C. P. Goerz, of Berlin. If this lens be adapted or modified for the photography of infinitely distant objects, it will offer great facilities for securing nearly perfect pictures over a very large field. If experiments on stars confirm this expectation, and if images of stars capable of being pointed upon with a probable error of a tenth of a second of arc at 3°, 4°, or 5° from the centre of the plate can be obtained, it would repay almost any amount of labour to investigate thoroughly the distortion errors of such a lens, and to apply it in combination with meridian

observations to a thorough triangulation and discussion of the positions of all zodiacal stars necessary for our further purposes. If such a lens can be found, the scheme can be very readily reduced to a practical form.

In observations of the Moon a decided advance seems possible, because the libration, thanks to the recent researches of Dr. Hartwig and Dr. Franz, is now known with great accuracy, and consequently the position of a well-defined spot near the Moon's centre can be referred to the limb (or, rather, to the centre of the Moon) with almost any desired precision. The position of this spot can then be referred to surrounding stars within 2° of the Moon's centre, with almost any desired precision, by means of heliometer observations. Observations by this method, however, would be limited to epochs within three or four days of full Moon, to avoid the possibility of apparent change in the position of the spot produced by change in the direction of illumination, unless, indeed, the positions of two other spots—one nearer the preceding, the other nearer the following, limb—can be also accurately referred to the Moon's centre. For observation in the Moon's first and last quarter, a great addition should be made to the list of occultation stars, and the necessary predictions of phenomena be computed for such observatories as are prepared to undertake the observations. Hardly sufficient attention appears to have been given to the accurate results obtained in this way by Dr. H. Battermann in his paper, "Beiträge zur Bestimmung der Mondbewegung und der Sonnenparallaxe aus Beobachtungen von Sternbedeckungen am sechsfüssigen Merz'schen Fernrohr der Berliner Sternwarte." The reduction by Dr. Ludwig Struve of the observations made at many different observatories, of the disappearance and reappearance of stars at the Moon's limb during the total eclipses of the Moon in 1884 and 1888, on plans proposed and elaborated by Dr. Döllen, reduces the outstanding error of the Moon's occultation diameter within very narrow limits. Future eclipses, similarly observed, will strengthen the determination. Dr. L. Struve's results, however, point clearly to the desirability of confining the observations to stars not fainter than the 8th magnitude.

Finally, we shall ere long have from the hands of Professor Newcomb a new series of homogeneous astronomical constants based on a complete discussion of all existing data, and new and more accurate tables of the planets similarly founded. Here also is the basis of a new departure!

Has not the time, therefore, arrived when practical steps should be taken to render the labour of those who undertake future work like that of Professor Newcomb, not only less laborious, but more satisfactory, than it has been in the past?

The ideal condition is that the geometer should not be required to undertake (as Professor Newcomb had to do) the reduction of vast masses of incongruous material to a homo-

geneous system—that it should be the business of practical astronomers so to arrange the methods and the partition of their work that their combined efforts shall produce all requisite results in a complete and uniformly digested shape for the purposes of those engaged in researches in astro-dynamics.

No one who has fully considered the subject, and experienced the earnest desire, which happily prevails amongst astronomers, to devote themselves to such work as that by which, with the means and opportunities at their disposal, the progress of science may be best advanced, can doubt that, by organised and combined effort, much greater things can be accomplished in the future than have been in the past.

To bring these general remarks to a practical conclusion, the following questions may be asked :—

1. Whether, in the opinion of astronomers generally, steps should be taken for a more complete and harmonious organisation and partition of the astronomical work of the world from the year 1900.

2. Are astronomers prepared to enter upon preliminary study, discussion, and experiment on the practical methods by which the art of observation may be raised to a higher level of accuracy, and its results be derived and published in a more systematic and homogeneous system ?

3. If these questions are answered in the affirmative, would it be desirable to hold an International Astronomical Congress, say in 1896, to discuss and make the necessary preliminary arrangements, and then let the definitive programme and partition of work be made at another general congress to be held in the year 1899 ?

Royal Observatory, Cape of Good Hope,
1894 *March* 16.

Note on Star Corrections in N.P.D. By W. E. Cooke.

(*Communicated by the Secretaries.*)

In a letter to the Astronomer Royal, dated 1894 January 23, Sir Charles Todd, the Director of the Adelaide Observatory, writes:—"Anything which will facilitate the reduction of our observations is so important that I shall not apologise for submitting to you a simple method which my first assistant, Mr. W. E. Cooke, M.A., has devised for reducing our Z.D. observations to mean N.P.D. January 1, respecting which I shall be glad to have your valuable opinion, and should it be favourable it may be brought before the Royal Astronomical Society."

The letter and notes on the method were handed by the Astronomer Royal to the Secretaries, who have drawn up the present note on the method.

The star correction in declination is, according to Bessel's notation,

$$Aa' + Bb' + Cc' + Dd',$$

where

$$a' = \tan \omega \cos \delta - \sin \alpha \sin \delta, \quad b' = \cos \alpha \sin \delta,$$
$$c' = 20''{\cdot}0524 \cos \alpha, \text{ and } d' = -\sin \alpha.$$

Of this expression part depends on both α and δ, part on α alone, and part on δ alone, as is seen by the alternative form of the correction tabulated in the *Nautical Almanac*, viz.:

$$i \cos \delta + g \cos (G + \alpha) + h \cos (H + \alpha) \sin \delta.$$

The procedure adopted by Mr. Cooke is (1) to leave untouched the computation of the part depending on both α and δ, i.e.,

$$h \cos (H + \alpha) \sin \delta,$$

or in the other notation

$$-A \sin \alpha \sin \delta + B \cos \alpha \sin \delta,$$

which is performed by the additions of two sets of three logarithms; (2) to simplify the computations of the other parts by tables and diagrams. The part $g \cos (G + \alpha)$ or $Cc' + Dd'$ is tabulated for each hour of R.A. and for every ten days throughout the year. On each night the values of this quantity are plotted in a curve for the hours of R.A. occupied in observation, and from this curve is read off the value of the term for every star in turn. Similarly, the part $i \cos \delta$, or $A \tan \omega \cos \delta$, is tabulated for every 10° of declination and every ten days throughout the year, a curve being constructed for each night of observation from the tables. These tables are of universal application, and if adopted at other observatories it might be advisable to extend them considerably.

It should be remarked that constants are added at various parts of the work to obviate the use of algebraic signs.

On Star Corrections. By Professor H. H. Turner, M.A., B.Sc.

1. The foregoing paper by Mr. Cooke affords an opportunity for putting down some notes on this subject, which has occupied my attention at intervals for some years past.

2. To the end of the year 1885 star corrections were computed at the Royal Observatory, Greenwich, by means of Airy's constants and day numbers, which were essentially those of Bessel, slight modifications being made so that algebraical signs were avoided. The day numbers were printed in the *Nautical Almanac* to the year 1890, but discarded when it was known that they were no longer required at Greenwich. The "star constants" were printed in the Greenwich Catalogues up to and including the Nine Year Catalogue 1872; and their computation was a serious addition to the labour of constructing the Catalogues.

3. There were several reasons for making a change, but the two chief were—

(*a*) The adopted procedure was found to be cumbersome.

(*b*) The use of the so-called "star constants" from year to year was found to be a fruitful source of errors, both because the numbers were not really "constants" and their slow change were apt to be neglected too long, and because errors were made in copying.

4. From 1886 January 1 Mr. Stone's "Tables for facilitating the computation of star constants" have been regularly used. All the computations are made independently in duplicate, and the results compared. A time about equivalent to the whole time of two computers is thus occupied in the computation of star corrections. If the meridian observing were in any way distributed in zones, this labour might of course be considerably reduced; but distributed, as it is at Greenwich, to all zenith distances indiscriminately, there is no way of reducing the labour except by simplifying the processes, if possible.

5. Mr. Finlay, in *Monthly Notices*, vol. l. p. 497, gives a method which certainly has advantages, and Mr. W. E. Cooke's method, given above, also seems to me to be a distinct simplification. My only doubt is whether the advantages gained in either case are quite sufficient, say, to make a change at Greenwich desirable. At the same time the question of saving labour is one of great importance, and the matter cannot be too thoroughly discussed. I have tried various methods during the last few years; in the first instance various forms of tabulation, which after many trials were found to be too cumbrous; and latterly different mechanical devices. At least four mechanical devices have been tried with fair success, as shown by models in wood and paper; but I do not propose to call attention here to more

than one of these—the last and simplest—which I hope will prove efficient.

6. The star corrections in R.A. and Decl. $\Delta\alpha$ and $\Delta\delta$ may be written, as on p. 297 of the *Nautical Almanac* for 1894,

$$\Delta\alpha = f + g \sin(G+\alpha) \tan\delta + h \sin(H+\alpha) \sec\delta \quad . \quad . \quad . \quad . \quad (1)$$

$$\Delta\delta = i \cos\delta + g \cos(G+\alpha) + h \cos(H+\alpha) \sin\delta \quad . \quad . \quad . \quad . \quad (2)$$

and the first of these equations may be written

$$\Delta\alpha \cos\delta = f \cos\delta + g \sin(G+\alpha) \sin\delta + h \sin(H+\alpha) \quad . \quad . \quad . \quad (3)$$

the expression on the right being now similar to that of equation (2).

Now all the terms in equations (2) and (3) may be represented under the form

$$p \sin(P+\alpha) \sin\delta,$$

where $\sin\delta$ is in some cases unity, i.e. δ may be put permanently equal to 90°. Thus a mechanical device which will give such a term at sight by setting for α and δ (p and P being set at the beginning of the series) would save the labour of entering three logarithms, adding, and taking out antilogs. There is, of course, nothing new in the principle of such devices; it only remains to settle the details, and I propose the following arrangement:—

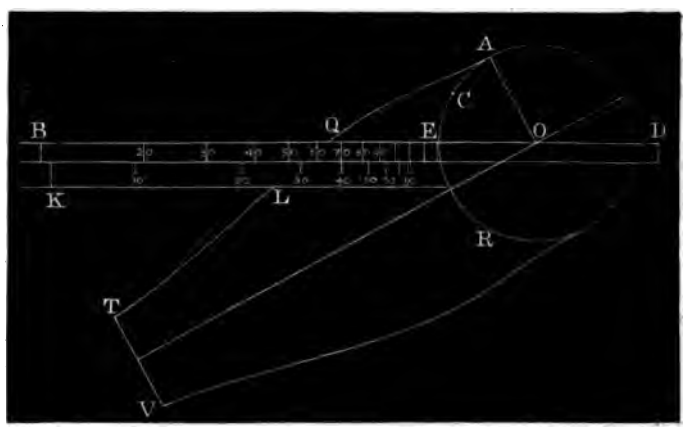


Fig. 1.

7. A graduated circle ACR can turn about O on a plate TAV. The point C is the zero, and R.A. is set off in the direction CR. The arc CA is set equal to the angle P (representing either G or H in the star corrections) and the circle then clamped to the plate. The plate and circle can now be turned about O until CE reads the R.A. of any particular star; and

thus the arc AE=(P+α). The plate VAT is so constructed that on any radius, OQ, the part EQ outside the circle is proportional to log cosec AE, or − log sin AE. So that if on a scale BD, BE represent log p, then

$$BQ = BE - EQ = \log p - \log \operatorname{cosec} AE = \log p \sin (P + \alpha).$$

If, further, another scale KL slide along BQD, and be graduated proportionally to log sin δ from left to right; and if the point corresponding to 90°, where

$$\log \sin \delta = 0,$$

be brought vertically under Q, then if S be a point on the scale BD vertically over the point for declination δ on KL, we shall have

$$\begin{aligned} BS &= BQ - QS \\ &= \log p \sin (P + \alpha) \sin \delta. \end{aligned}$$

The operations thus consist of the following:—

(a) *Preliminary*, applying to the whole of a set: Turn the circle on the plate until AC=P, and clamp circle on plate. Slide BD until the point corresponding to p is on the limb of the circle and clamp BD. It would be well to have lenses or even microscopes, at least for these permanent settings.

(b) For any star α, δ: Bring α to E, the edge of BD; set the 90° mark on KR under Q, where the plate cuts BD, and read off the point S on BD vertically over δ. There should be no difficulty in doing this if BD be graduated on both edges.

8. This being the general principle several small modifications of detail suggest themselves. In the first place we have *two* terms involving G and g and two involving H and h. Consider the first. If we have a scale B′D′ precisely similar to BD but at right angles to it, and cutting the circle in E′, the plate in Q′ &c., then if

$$\begin{aligned} BQ &= g \sin (G + \alpha) \\ B'Q' &= g \cos (G + \alpha). \end{aligned}$$

Thus the two terms g sin (G+α) sin δ, required for $\Delta\alpha$ cos δ, and g cos (G+α), required for $\Delta\delta$, can be read off at one setting. Similarly writing (H+90°) for G, the other two terms can be found at one setting. No subsidiary scale KLR is necessary for the scale B′D′, since sin δ only occurs in one term of each pair.

Secondly, in all logarithmic scales there is a great inconvenience arising from the length to which they extend for the small quantities. The length for the portion 0·1 to 1·0 is as great as that from 10 to 100, or from 100 to 1,000, and is, of course, precisely similar. We can thus take advantage of this fact by using the same portion twice or three times over, always remembering to divide by 10,

or 100, or 1,000, as the case may be. Thus the plate VAT is terminated abruptly at T, whereas it should really

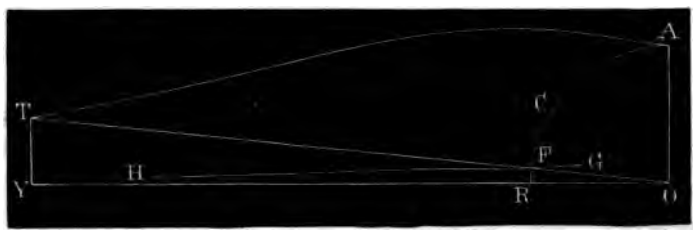


Fig. 2.

extend to infinity. The point T corresponds to the angle 5° 44′, whose sine is 0.1. If OT cut the circle in F, and GFH be drawn so that excess of radius vector is proportional to log. cosec (angle) − 1, or log. $\left(\frac{1}{10}\text{ cosec angle}\right)$, instead of log. cosec (angle), then the curve GFH will read off on the scale

Fig. 3.

BQD *ten times* the corresponding term, and may be used for small angles. Similarly another curve may be drawn reading off *one hundred times* the term for smaller angles still.

Again, the scale for δ need not be of more than a moderate length; it need not, in fact, extend beyond 5° 45′ if below the portion 90° − 5° is placed another portion corresponding to log. (10 sin δ) or 1 + log. sin δ instead of sin δ, and below this another corresponding to log. (100 sin δ) or 2 + log. sin δ. The scale BD need thus not be extended beyond modest limits. I think convenience would be sufficiently consulted, and sufficient accuracy attained, by making the portion from log. 10 to log. 100 equal to one metre, though a smaller contrivance than this might answer.

9. The above was already in type when a series of simpler contrivances suggested themselves, which promise to be many ways more efficient. It will, I think, be of interest to describe four successive devices which are all comparable in efficiency, though the last will probably turn out the best. The

use of a logarithmic scale, with the inconveniences detailed in paragraph 8, is discarded in the following apparatus.

10. On a drawing board VQ (fig. 1) are drawn a series of "curves of sines" AC_1B, AC_2B, AC_3B, &c., the maxima OC_1, OC_2, OC_3, &c., being respectively 30, 29, 28 . . . . 2, 1, 0 units —say, half-inches—and representing 30″, 29″, 28″ . . . . 2″, 1″, 0″. The base AB being divided uniformly from 0^h to 12^h, as at DE,

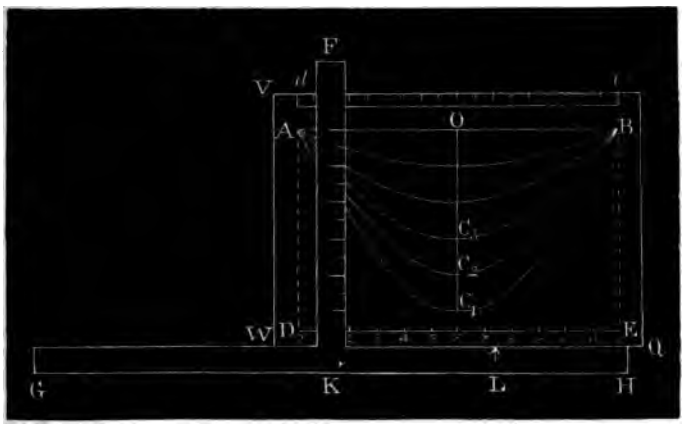


Fig. 4.

or from 0° to 180°, as at *de*, ordinates to any one of the curves, say, maximum 28″, give the values of 28″ sin a for the various R.A.'s or angles from 0^h to 12^h; and a T square FGKH whose T slides along the base WQ of the board, and whose edge FK is graduated uniformly, may be used to read off the value of this quantity by noting the point where the curve 28″ cuts its edge when slid to the proper R.A. If the value of 28″·3 sin a is required, we must interpolate between the curves for 28″ and 29″, either by eye or by actually drawing the 10 intermediate curves, which is not difficult on the scale suggested. Thus we see how to read off p sin a, where p has any value from 0″·0 to 30″·0. To read off p sin $(P+a)$ we merely alter the index on the T square from K to some other point L such that when L points to a, K points to $(P+a)$, or $LK=-P$. Thus L is constant in position for the day. An ink mark on a piece of paper gummed temporarily to GH would be an adequate index.

Now to form p sin $(P+a)$ sin δ we merely move the square to δ (taking now the top scale *de* divided in degrees) and read off the value of the curve whose maximum is p sin $(P+a)$, as already found.

When once the curves are nicely drawn this makes a very efficient machine. Its one drawback is the difficulty of following the curves, when these are numerous enough to give sufficient

accuracy. To obviate this the apparatus of the next paragraph was devised.

11. Instead of many curves, a single curve AC_1B would be sufficient if we could vary the scale on FK so as to make it read p units at the point C_1. Now a scale can be varied by the device used in the "diagonal scale." If the line OA (fig. 5) be divided

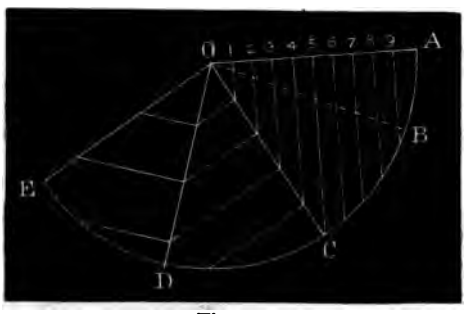


Fig. 5.

into ten equal parts, and perpendiculars be erected to OA at each point, then any other radius OB of the same length as OA will be divided uniformly into a smaller number of parts. For

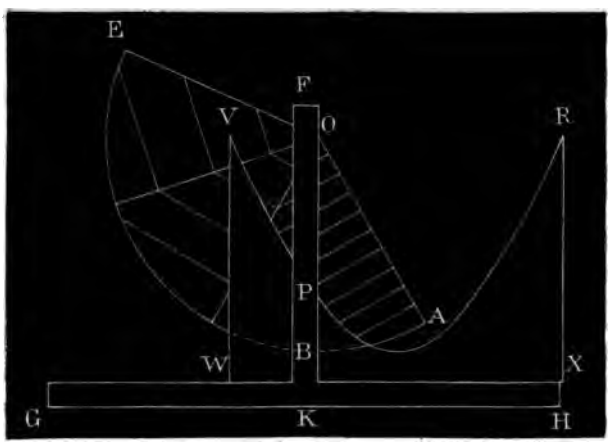


Fig. 6.

convenience new perpendiculars may be drawn at any other radius OC, OD, &c. Let us call a circular sector so divided a "reducing scale." Thus if FGH (fig. 6) be again our T square, and a reducing scale OAE be pivoted at O on the edge FK, then the maximum ordinate OB can be divided into any arbitrary number of parts p by rotating the reducing scale. Let us now cut out of card a single sine curve VAR,

which may be slid beneath the arm FK of the T square, the edge WX of the card bearing against the T of the square. Then the ordinate OP will be $p \sin (P + \alpha)$, as before, if the index be adjusted so that $(P + \alpha)$, and not α simply, be read off on the sliding scale.

12. So long, however, as we use a *slide* for setting in R.A. we get the sine curve entering into the machine. If the R.A. is to be set off on a uniform scale—which is practically a necessity if we are to form the sum $(P + \alpha)$ mechanically—we are limited to two methods—those of translation and of rotation. It is curious that I should have dwelt so long upon the *slide* for R.A., for the graduated circle is obviously more appropriate. But one seldom thinks of the simplest thing first, and it was not until I had made one or two machines of the above type that it struck me to try setting off the R.A., not on a straight line, but on a circular arc. The curve now to be used is no longer

$$y = a \sin x + b,$$

but

$$r = a + b \sin \theta,$$

where a and b are constants. It is obviously simplest to take $a = 0$, when the curve is a circle and can be described mechanically with great ease. The apparatus now becomes modified as

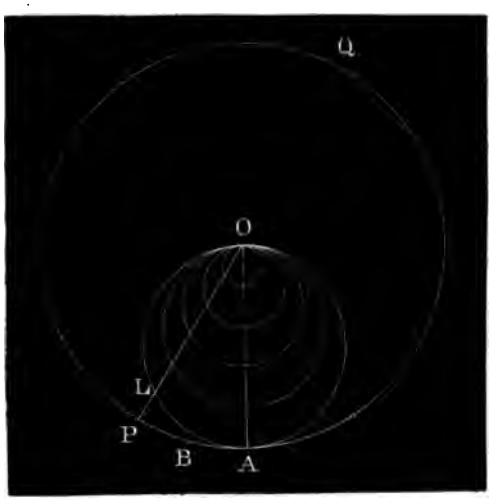


Fig. 7.

follows: The R.A. or declination is set off on the rim of a circle APQ, but so that the zero point can be shifted arbitrarily to any point B, where AB is made equal to P. A series of circles are described, all passing through O, and with diameters 30″, 29″, 28″, &c. . . . . 2″, 1″, corresponding to the series of sine curves in paragraph 10 (fig. 7). Then if $BP = a$, so that $AP = P + a$, it

is easily seen that OL=OA cos (P+α), and the value of p cos (P+α) can be readily found by tracing the circle corresponding to the value p up to the radius OP, which should be a divided scale.

13. But finally the circles need not be actually drawn, and herein consists the great simplicity of what I believe to be the final device. If OT (fig. 8) be the length p, and if OP be a straight-edge, and a set-square MLK be slid along OP so that the edge

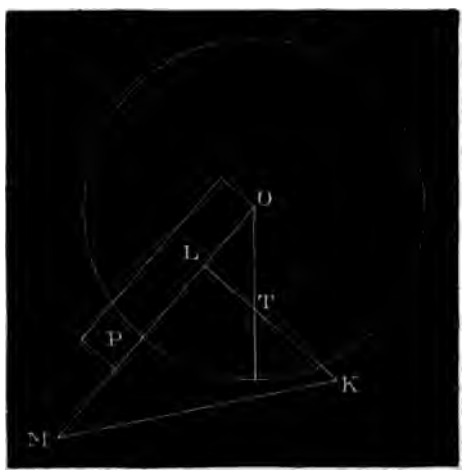


Fig. 8.

LK passes through T, then obviously OL=OT cos (P+α), LT=OT sin (P+α); in fact, we have arrived by a roundabout route at the very simplest method of finding the sine and cosine required by actually constructing the triangle of which they are the sides, viz. OLT. The final machine I suggest is, therefore, as follows (fig. 9). I describe it in terms of wood and paper, though a more exact apparatus can obviously be made in metal.

On a drawing board covered with white paper a circle is drawn, and carefully graduated. (It is convenient to have graduations extending from the point A in the direction AD in degrees, and in the direction AE in hours and minutes.) A straight-edge POP′ is pivoted at O on its edge (a piece of paper may be gummed on in order to make a hole for the pivot), and graduated uniformly from O outwards. A set-square MLK, graduated on one edge LK, completes the apparatus. (The edge LK should also be graduated *on the back*, so that the set-square may be reversed if necessary. The straight-edge may be reversed by simple rotation.)

To form the terms p sin (P+α) and p cos (P+α) first find the position of the point T for the day by turning the scale OP

to the point D, where AD=P, and setting off OT=p. Then, when OP is turned to any right ascension α, where AE=α, we have EOD=(P+α), and if the set-square be slid up to the point T the distances LT and OL, which can be at once read off the scales, are the quantities required. The point T may be marked

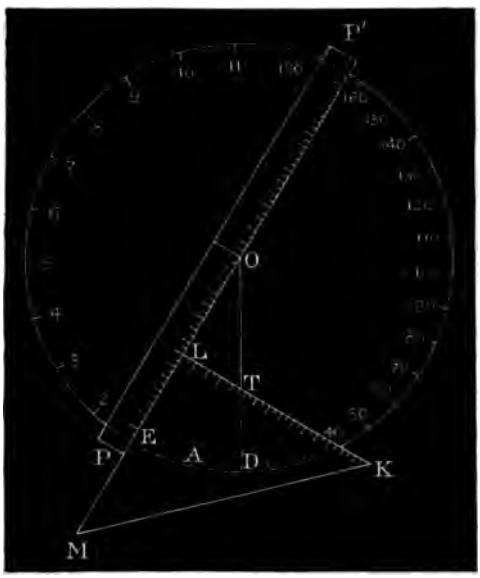


Fig 9.

for the day by an ink dot. The successive positions of these dots will form a curve which may be laid down on the paper for a whole year, and dates attached to the proper points.

14. This brief description of the machine will probably be sufficiently intelligible, and, as I have not yet had an opportunity of trying it thoroughly in practice, any practical comments are more fitly reserved for a future occasion. But I cannot but think that a simple apparatus of the kind will at least be found of great use in *checking* computations, though it may be advisable to make the computations originally in figures.

Graduating Wedges. By Captain W. de W. Abney, C.B., R.E., D.C.L., F.R.S.

In some cases where wedges are very opaque it becomes difficult to arrive visually at the correct graduation, as light from an ordinary source, such as a lamp, will not pass through with sufficient quantity to enable an accurate measure to be made. The light which it seems most desirable to employ is the electric (arc) light, since it is far more luminous than a lamp or candle, and it has the advantage that a large quantity of light is emitted from what is practically a point. There are, however, variations in the electric (arc) light from time to time, and unless the comparison light, with which the relative intensities passing through different parts of the wedge are measured, varies at exactly the same time and in the same proportion, the measurements will often be very much out. If we merely wish to measure the white light transmitted, the apparatus to employ is not very extensive, and fig. 1 will show what it is. EL is the electric light placed in a lantern or box of some kind, to prevent the room, which should be slightly darkened, from being flooded with bright white light. L_1 is a condenser which

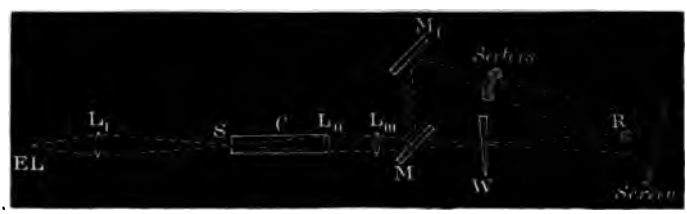


Fig. 1.

throws an image of the crater of the positive pole upon the slit S of the collimator C. The rays issue parallel and are caught by a lens L_{III}, which forms an image of the slit upon the surface of the wedge W, placed in a proper position and in its mountings. The light after passing through the wedge forms a circle of light on the screen. It will be noticed that the image of the slit may be as narrow as one wishes by opening or closing S, and that we have a line of light passing through the wedge, such as is required to effect the graduation. Calculation will show that with a fairly narrow slit the measured intensity passing through it may be taken as that passing through the mean thickness of that part on which the image falls.

Placed in the path of the beam, and between the wedge and L_{III}, is a plain mirror M (for which I often substitute a prism of $1\frac{1}{2}°$, and so obtain a single reflection), which reflects the light at right angles, or any convenient angle to its path. It is again

reflected from M_1, a silver on glass mirror. An image of the slit is formed in the path and a second disc is formed on the screen. The centre of this disc is made to coincide with the centre of the disc formed by the light passing through the wedge. A rod R is placed in the path of the two beams, which casts two shadows, one illuminated by one beam and one by the other. The usual black mask is used on the screen, to confine the attention to a small part of the shadows.

It will be seen that when any variation takes place in the light it equally affects both the illuminated shadows; hence the measures may be made without fear of error creeping in. Sectors with apertures, movable at will whilst they are rotating, are introduced, as shown in the figure, and sometimes a second set of fixed sectors are introduced between M and W should the light passing through W be too bright. The screen is placed perpendicular to the line bisecting the angle made by the two beams. It should be noted that this plan almost necessitates movable sectors, but sectors which are fixed at known apertures can be used at a pinch, and the balance made by moving the wedge in its settings.

It should be remarked that though the wedge may not be pure black the readings can be very readily made by the method of oscillating between "too light" and "too dark" for the

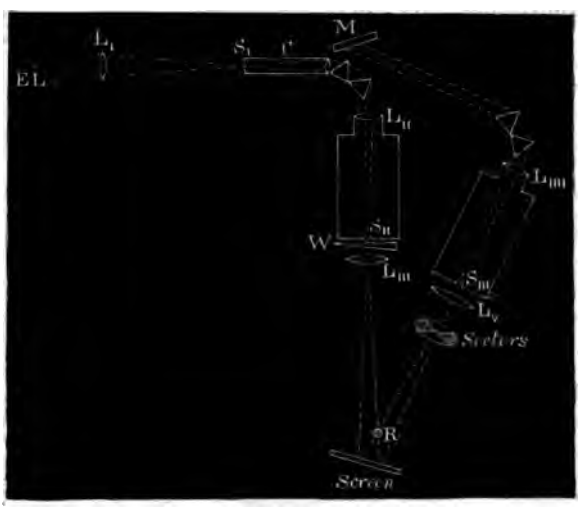


Fig. 2.

shadow whose brightness is controlled by the sector. In making a valuation of the wedge, the first thing to do is to compare the lights without the intervention of the wedge, and then to take readings.

For certain purposes it is necessary to know how much of each colour of the spectrum is transmitted through a wedge, and fig. 2 shows how this is accomplished.

The electric light and the collimator are placed as before, but the parallel emergent rays fall upon a pair of prisms, and the spectrum is brought to a focus by L_{II} on to a screen in which there is a slit against which the wedge in its setting is placed. The slit can be placed in any spectrum ray, and the wedge surface is always kept perpendicular to that ray. A lens L_{III} brings the rays to a focus, so that a monochromatic image of the surface of the last prism is formed on the screen. From the surface of the first prism parallel rays are reflected: these are caught by a mirror and fall on a pair of precisely similar prisms, and the remainder of the apparatus is exactly the same as that described above, a second patch of coloured light being formed over the first patch. The slit S_{III} is so adjusted in the spectrum that the two patches are of the same colour. The sectors are placed as shown in the figure, the rod R forming two shadows, as before. The method of procedure is to place the slit S_{II} in some colour in the spectrum, and S_{III} in the same. The wedge is then graduated for this beam throughout its length, another position is taken up and the same process gone through. By this means we get the logarithmic factor of transparency for each part of the wedge for the whole of the spectrum colours. As I have mentioned in another paper, the factor most essential to know for extinction purposes is that for the part of the spectrum near the Fraunhofer line E.

Photograph of the Cluster M. 46, *and of the Nebula* H IV. 39 *Argûs*.
By Isaac Roberts, D.Sc., F.R.S.

The photograph of the cluster M. 46 and of the nebula H IV. 39 *Argûs*, R.A. $7^h\ 37^m$, Decl. 14° 30′ south, was taken with the 20-inch reflector on 1894 February 24, with exposure of the plate during 90 minutes, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The cluster is No. 2437 in the *New General Catalogue*, and 1564 in the *General Catalogue*. The nebula is No. 2438 in the *New General Catalogue*, and 1565 in the *General Catalogue*.

Sir J. Herschel describes the cluster as a remarkable object, very bright, very rich, very large, with a planetary nebula involved, which he describes as pretty bright, pretty small, extremely little extended, barely resolvable.

Lord Rosse (*Phil. Trans.*, 1850, p. 513, Pl. XXXVIII., fig. 12, and *Observations of Nebulæ and Clusters of Stars*, p. 61) records twenty-one observations of the nebula made between the years 1848 and 1876. He saw it first as a planetary nebula 60″ in diameter, and subsequently as an annular nebula with two stars, and a suspected third star, in it. Much uncertainty as to the character of the object is shown by the records, and in

the last observation (1876) he says, "It can hardly be called a planetary nebula."

The star *n.p.*, the centre, is estimated as of 13th–14th magnitude, and the other star near the *following* edge 16th magnitude.

Lassell (*Mem. R.A.S.*, vol. xxiii. p. 60, Pl. II. fig. 5) describes it as a planetary nebula, and saw two stars in it.

The photograph leaves us in no doubt as to the character of the nebula. It is an annular nebula, as perfect in outline as M. 57 *Lyræ*, and is seen projected on a plane facing the eye and circular in form. The ring is most condensed on the *n.f.* side, but no distinct central nebulosity is shown, and there are three stars in the interior: the brightest of them (13th–14th magnitude) is near the centre; another, of about 16th magnitude, is on the *s.p.* side; and the third, which is below 16th magnitude, is almost involved in the ring on the *s.f.* side. There is also evidence of very faint condensations of nebulosity in the ring itself.

The nebula, as the photograph clearly shows, is either involved or else in alignment with the northern part of the cluster, which is a magnificent aggregation of stars between 9th and 16th magnitude, and the photo-fields around it are crowded with stars having the usual remarkable groupings, and numerous apparent double, triple, and multiple stars. Some years hence these rich photo-fields of stars and their groupings will afford delightful studies for our successors by the aid of photography.

Photograph of a "New" Spiral Nebula in Perseus. By Isaac Roberts, D.Sc., F.R.S.

The Spiral Nebula is in R.A. $2^h\ 29^m\ 58^s$, Dec. 38° 31′·4 *north*, Epoch 1895. It is $3^m\ 51^s$ *preceding* and 5′·4 *south* of $\frac{H}{G}$ I. 156 *Persei*; both nebulæ are visible on the same photograph.

I assume this nebula to be new to science for the reasons that it is very faint, and is not recorded in the *New General Catalogue* or in the supplement to it, a manuscript copy of which Dr. Dreyer kindly sent me.

The convolutions of the spirals are very faint, but clearly visible on the negative, and involved in them are four 14–15 mag. stars and 6 or 7 stars, or star-like condensations, less bright than 16th mag. The convolutions are symmetrical, and proceed from a very faint star-like nucleus.

Photograph of the Nebula $\frac{H}{G}$ I. 156 *Persei.* By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebula $\frac{H}{G}$ I. 156 *Persei*, R.A. $2^h\ 33^m\ 49^s$, Dec. 38° 36′·8 *north*, was taken with the 20-inch reflector on 1893 December 29, with exposure of the plate during three hours, an enlargement of which to the scale of 1 millimetre to 24 seconds of arc is now presented.

The nebula is No. 1023 in the *New General Catalogue* and 575 in the *General Catalogue*.

It is described by Sir J. Herschel (*General Catalogue*, p. 56) as very bright, very large, very much extended, very very much brighter in the middle, lenticular, 5′ long. A drawing of it is given in the *Phil. Trans.* for 1833, Pl. XIV. fig. 56; but the nebula is drawn too pointed at the ends, and none of the stars involved in it are shown.

Lord Rosse in the *Phil. Trans.* for 1861, p. 713, Pl. XXV. fig. 5, and *Observations of Nebulæ and Clusters of Stars*, pp. 30, 31, records 13 observations of the nebula between the years 1850 and 1877. He saw 6 stars involved in it, and an oval nucleus; and about 20′ *preceding* the nebula saw a star of 8th or 9th mag. with what appeared to be an atmosphere round it.

The photograph shows the nebula with a distinct stellar nucleus and extensions of faint nebulosity in the *preceding* and *following* directions. On the *south following* side the faint nebulosity is seen to trend southwards, and suggests the idea that the nebula is either circular or an oval seen edgewise, the central star or nucleus being visible through the nebulosity in the direction of the semi-axis minor.

The nebula, as it is drawn by Lord Rosse in the *Phil. Trans.* for 1861, is in fair agreement with the photograph, and he shows five of the seven stars involved in it, and refers to having seen six stars. There is nothing about the 9th-magnitude star 20′ *preceding* the nebula, to which he refers, indicative of an atmosphere, as he suggests, nor does the star present any appearances differing from the other stars. The nebula is surrounded by very rich fields of faint stars, forming curves and festoons, such as are usually seen on all photographs taken with long exposures of the plates to the sky in the proximity of the Milky Way. Apparent *comites* and multiple stars are also numerous.

Admiral Smyth (*Cycle of Celestial Objects*, second edition, p. 67) states that he saw the nebula very distinctly with his instrument as an ellipse, and that it trends (as shown in his sketch, and also in Lord Rosse's sketch and drawing, and in Sir J. Herschel's drawing) in *north following* and *south preceding* directions at a position angle of about sixty degrees; but the photograph shows it to be just on a parallel of declination. It is difficult to reconcile this discrepancy upon the assumption of a change so large in the position angle of the major axis of the nebula within the interval of about eighteen years. On the other hand, it is difficult to realise that the three competent and independent observers named have each made so obvious an error in delineating the position angle.

If Admiral Smyth saw this very faint nebula as an ellipse, it is remarkable that he did not also see the stars involved in it, six of which were seen by Lord Rosse and are shown (seven in number) on the photograph, four of them being much brighter than the nebulosity.

Notes on some Photographs taken with a Visual Telescope.

By H. F. Newall, M.A.

During the past six months several photographs of stars, &c., have been taken with the Newall telescope of the Cambridge Observatory with a view of testing the performance in photographic work of a large telescope constructed for visual work. I beg leave to show to the Society some of the results obtained.

These results may best be set forth if I describe the individual photographs exhibited, explaining at the same time the object aimed at in each attempt. The experiments have been made at considerable intervals, whenever, for some reason or another, spectroscopic work was not possible or convenient. Hence the information has been gathered slowly and under very varied conditions (as to temperature, &c.)

Some details are here given concerning the instrument, since a knowledge of them is necessary to a discussion of the images obtained:

Aperture of the object-glass	24·8 inches	630 mm.
Focal length	29 ft.	8844 mm.

Ratio focal length ÷ aperture = 14·04

The crown and flint lenses are separated only by the thickness of tinfoil.

Details concerning the colour correction of the object-glass:

	Inch.	Millimetre.	
[H_α (C)	− 050	− 1·25 added April 23]	
Minimum between D and *h*	− ·159	− 4·04	Mean of 6 determinations made in course of 2 years with different slit spectroscopes by the Harkness-Vogel method.
H_β (F)	·000	·000	Deduced from photographs of the spectrum of *Polaris* taken with objective prism in front of object-glass; aperture used 10½ inches.
H_γ (G′)	+ ·45	+ 11·4	
H_δ (*h*)	+ 1·07	+ 27·2	
H_ϵ (H_1)	+ 1 50	+ 38·1	
H_ζ (Huggins' α)	+ 2·25	+ 57·2	

Note.—Many slightly discrepant determinations have been made of the chromatic aberration in the red, yellow, and green. The sources of discrepancy are not yet perfectly clear, but there are indubitable signs of a temperature coefficient of considerable importance. The separation of minimum and $H\beta$ foci given above is therefore to be regarded as provisional. In the appearance of star images on warm and cold nights the differences of the colour correction are quite noticeable in careful observation.

To facilitate comparison with other large refractors I append the following table:

Line and Wave-length.	Vienna Telescope. df mm.	$\frac{h}{f}$	$\frac{df}{f} \times 10^5$	Pulkowa Telescope. df mm.	$\frac{h}{f}$	$\frac{df}{f} \times 10^5$	Lick Telescope. df mm.	$\frac{h}{f}$	$\frac{df}{f} \times 10^5$	Newall Telescope. df mm.	$\frac{h}{f}$	$\frac{df}{f} \times 10^5$
H_α (C) 656	2·7	·000017	26	3·0	·0000115	21	5·3	·0000162	31	3·1	·0000250	35
D 589	0·0	·000	0	0·0	·000	0	0·0	·000	0	0·0	·000	0
H_β (F) 486	6·0	·0000378	58	6·4	·0000245	45	11·4	·0000349	66	4·0	·0000323	45
H_γ (G′)434	23·5	·0001478	227	32·9	·0001258	233	48·3	·0001471	281	15·4	·0001243	174
H_δ (*h*) 410	...	...	...	...	...	...	81·5	·0002484	474	31·2	·0002518	353

Aperture	27 in. 675 mm.	30 in. 762 mm.	36 in. 914 mm.	24·8 in. 630 mm.
Focal length	34 ft. 10,360 mm.	46 ft. 14,120 mm.	56½ ft. (?) 17,200 mm.	29 ft. 8,844 mm.
Ratio $\frac{\text{F. L.}}{\text{Ap.}}$	15·3 : 1	18·5 : 1	19·1 : 1	14·0 : 1
Glass cast by	Feil	Feil	Feil	Chance
Glass worked by	Grubb	Clark	Clark	Cooke
Date	1881	1883	1886	1868

[*Note added April 23.*—The numbers given for the Newall telescope are based, so far as the visual part of the spectrum is concerned, on determinations made under very favourable conditions on April 21. The temperature in the dome at the time was 38° F. (3°·3 C).]

Plate No. 1.—For a study of the chromatic aberration of the object-glass in the region of the foci for violet and ultra violet light.

1894 March 29. 8.33–10.11. Spectrum of *Polaris.*

Plate: Edwards's instantaneous isochromatic.

South Kensington objective prism, 10½ inches aperture, mounted in front of the central part of the object-glass of the equatorial.

Nine exposures, 10 minutes each, with change of focus between successive exposures by first three equal movements of $\frac{3}{16}$ inch from visual focus, and lastly five equal movements of $\frac{3}{8}$ inch up to 2¼ inches from visual focus.

The driving clock of the equatorial was so rated that the spectrum did not trail on the plate, as in the usual method adopted in photographing spectra with an objective prism. Thus the width of the spectrum in that region which was in focus on the plate was very small. The width in the narrowest part near H_δ (*h*) at focus +1 inch was found by measurement to be 2″·14 (0·092 mm.).

The plate shows very clearly the travelling of the focussed part of the spectrum from the yellow to the violet end of the spectrum, as the plate is drawn out further and further. The method gives good reliable results between H_β (F) and the ultra violet, but not in the green and yellow. The line H_β (F) forms, however, an excellent connecting link between determinations made in the method above described and the usual spectroscopic method due to Harkness and employed by Vogel and others.

From this plate the results given in an earlier paragraph were deduced.

Plate No. 2.—For a study of the spherical aberration of the object-glass.

1894 March 29. 12.10–12.45. *Polaris.*

Plate: Edwards's instantaneous isochromatic.

Screen: Dark yellow glass.

Nine exposures: three for central circular aperture, 6 inches in diameter, for 2 minutes each—one at the visual focus, the other two at $+\frac{3}{16}$ inch and at $-\frac{3}{16}$ inch; three for exterior annulus, with external radius 12 inches, and with internal radius 11½ inches, for 2 minutes each, with same focussing as in the first case; three more with the same annulus and focussing, but with 3 minutes' exposure.

The images are very satisfactory in both cases, and careful comparison shows that the images at that focus which was called "visual," and which was determined with 24 inches aperture,

are distinctly better than the images obtained either $\frac{3}{16}$ inch inside or $\frac{3}{16}$ inch outside that focus.

Though the areas of the central and annular apertures are in the ratio of 9 to 12, still the plate shows that while an exposure of 2 minutes is enough for the central aperture, an exposure of 3 minutes is hardly enough to give comparable images with the (larger) annular aperture.

Inspection of the images with an eye-piece makes clear the need for the longer exposure when the annulus is used. The effect of atmospheric tremor is to give rise to rays round the central image. The rays are in constant movement round the centre, sometimes long (10″), sometimes short (2″); they are therefore not the result of defect in the glass, but are due to a momentary annulling of the contribution of disturbance which should come from some part of the annulus, but which, from those atmospheric causes that give rise to "bad seeing," is suppressed, leading to an upset of that balance necessary by the principles of the undulatory theory of light to the formation of a perfect image. In consequence of these moving rays, the light which in perfect conditions of seeing would be concentrated within a very small area is generally spread over different parts of an area having a diameter of 20″ or 30″, and is only for a moment now and then collected into a circular disc without the constantly moving rays.

Plate No. 3.—For a study of the effect of change of focus on the size and appearance of the photographic image of a bright star.

1894 January 18. 10.30–10.50. *Procyon.* (Mag. Oxon. Uranom. 0·5)

Plate: Wratten and Wainwright, "drop shutter."

No screen.

Thirteen exposures, thirty seconds each, with change of focus betwen successive exposures, by equal movements of $\frac{3}{16}$ inch from visual focus to a focus $2\frac{1}{4}$ inches outside the visual focus.

Focus.	Appearance of Image.
"Visual"	Blurred image about 100″ diameter, with ragged edge; increasing density to the centre; no defined nucleus.
(50) + $\frac{3}{16}$ inch	Smaller diameter, but similar to last.
(100) + $\frac{3}{8}$ "	" " distinct nucleus now appears.
(150) + $\frac{9}{16}$ "	Similar to last; smaller diameter.
(200) + $\frac{3}{4}$ "	" " diameter about 60″.
(250) + $\frac{15}{16}$ "	Smaller diameter; small disc within the ragged edge; defined nucleus.
(300) + 1 $\frac{1}{8}$ "	Ragged edge disappearing; disc increasing; nucleus still defined.
(350) + 1$\frac{5}{16}$ "	No ragged edge; disc, 43″·8 in diameter; defined nucleus. Smallest image.

From this point onwards the appearance does not change; the diameter steadily increases; edge, comparatively speaking, clean cut; nucleus quite definite. Diameter at $2\frac{1}{4}$ inches about 100″.

The plate also has on it images of Bird's double (0″·8), which is equivalent to a star of about the 8th magnitude. The appearance of the image hardly changes at all. It may be described as a small nucleus with ragged edge about 8″ or 10″ in diameter. The most intense nucleus is that at focus $+1\frac{1}{8}$ or $+1\frac{5}{16}$ inch.

Further, a small image of an 11th magnitude star is seen on the plate.

From the chromatic aberration curve deduced from the photographs of the spectrum of *Polaris* it appears that the best image on the plate now under consideration is that formed when the plate is placed at the focus for H_δ (h); a result which falls in completely with expectation based on a knowledge of the curve of sensitiveness of the photographic plates used, and the distribution of the foci for different wave-lengths along the axis of the equatorial.

The undulatory theory demands that with a perfectly figured object-glass the intensity of light at the centre of the diffraction pattern should be proportional to the fourth power of the aperture. Whilst it is improbable that practically this can be fulfilled, still it appears that the existence of the nucleus in the image is connected with this concentration of light in the focussed image amidst the superposed circles of aberration of the light coming from foci behind and before the plate.

Plate No. 4.—For a study of the applicability of dry collodion plate.

1894 February 3. 13 10–13.55. *Procyon.*

Plate: Hill Norris. Dry collodion, yellow label.

No screen.

Full aperture.

Twenty-five exposures: five exposures, $\frac{1}{4}^m$, $\frac{1}{2}^m$, 1^m, 2^m, and 4^m at each of the following focussings: visual, $+\frac{3}{16}$ inch, $+\frac{3}{8}$ inch, $+\frac{9}{16}$ inch, $+\frac{3}{4}$ inch.

Good small images about 5″–10″ diameter are got of the bright star (mag. 0·5); but the image of an 8th magnitude star only begins to be visible on the plate after 4 minutes' exposure. The best image is got with focus $+\frac{3}{8}$ inch, that is, at the focus of light with wave-length intermediate between H_β (F) and H_γ.

Plate No. 5.—For a study of the appearance of star images on an isochromatic plate, a light yellow screen being used; also for a study of the change of appearance of such images with varied exposures.

1894 January 23. 9.49–10.43. *Procyon* (mag. 0·5).

Plate: Edwards's instantaneous isochromatic.

Screen: Light yellow screen.

Aperture: full, 25 inches.

Twenty-five exposures: five at visual focus with the following exposures: $\frac{1}{4}^m$, $\frac{1}{2}^m$, 1^m, 2^m, 4^m; five similar exposures at

each of the following focussings: $+\frac{3}{8}$ inch, $+\frac{3}{4}$ inch, $+1\frac{1}{8}$ inch, $+1\frac{1}{2}$ inch.

The most definite "discs" are got at the focus $+\frac{3}{4}$ inch. There is no ragged edge; the disc does not increase much in size with lengthened exposure. The following measures were made of the discs of *Procyon* at focus $+\frac{3}{4}$ inch:

Exposure	$\frac{1}{4}^m$	$\frac{1}{2}^m$	1^m	2^m	4^m
Diameter	33″·32	34″·02	34″·25	34″·48	35″·65

Probably the best focus for a photograph intended for measure of images of neighbouring bright and faint stars would be $+\frac{3}{8}$ inch. An 8th magnitude star shows well with an exposure of $\frac{1}{4}^m$; the diameter of the image is about 3″, and though the edge is not very definite, bisection with a micrometer wire would be easy. In none of the twenty-five exposures does the image of the 8th magnitude star exceed 5″ in diameter. The images at visual focus are the best. But, as has been stated above, for measures of bright *and* faint stars the images at focus $+\frac{3}{8}$ inch would probably prove best.

Plate No. 6.—For a study of the effects of diminishing the circles of aberration by cutting down aperture; and for a trial of medium sensitiveness in isochromatic plates.

1894 April 4. 11.10–12.24. *β Geminorum* (mag. 1.36).

Plate: Edwards's medium isochromatic.

Screen: Light yellow glass.

Twenty-four exposures: five exposures with 24-inch aperture, $\frac{1}{4}^m$, $\frac{1}{2}^m$, 1^m, 2^m, and 4^m, at each of the following focussings: $\frac{3}{16}$ inch, visual, $+\frac{3}{16}$ inch; five exposures with 12-inch aperture durations as above, all at $+\frac{3}{16}$ inch focus; four exposures with 12-inch aperture, durations 1^m, 2^m, 4^m, 8^m, all at visual focus.

The images obtained with the smaller aperture are excellently good discs, but so small for so bright a star as *β Geminorum* (Mag. Oxon. Uranom., 1·36) as to make one fear that long exposures would be needed for fainter stars.

Plate No. 7.

1894 March 23. 11.35–11.45. *Castor.*

Plate: Edwards's instantaneous isochromatic.

Screen: Dark yellow glass.

Plate set at the visual focus behind a Thornton-Pickard spring shutter.

Twelve exposures: longest 8 seconds, shortest 2 seconds.

The images of the two components are in all cases distinctly separated, and are easily measurable discs of small dimensions. The seeing at the time the plate was exposed was fair. The position angle is, even in casual inspection, obviously different in the different exposures; a fact which must be attributed to atmospheric tremor. No measures of the position angle

have been made, but the following results of measurement of the separation of the centres are of interest. Five bisections of each component in each pair were made.

Exposure.	6 sec.	4 sec.	2 sec.	4 sec.	6 sec.	8 sec.
Distance	5″·71	5″·75	6″·01	5″·66	5″·78	5″·52
Probable error	±0·0061	±0·0103	±0·0063	±0·0065	±0·0097	±0·0082
Character of image	good round disc	good round disc	small star, faint, but easily seen	elongated discs	bad shape; triangular	round with small excrescence on one side

Diameters of star images in the exposure of 8 seconds:

Large star (single reading of each edge)	4″·03
Small star „ „ „	2·56
Separation of nearest edges	2·51
Deduced separation of centres	5·805

There is evidence of diminution of measured separation with increased exposure. Such diminution is what one would expect from the fact that each component falls on a part of the plate already illuminated by the other component, with the result that the image of each component grows more rapidly on the side near to the other component than on that remote from it. In bisecting the images with the micrometer, a false centre is taken.

The effects of the chromatic aberration of such a telescope as the 25-inch equatorial at Cambridge make themselves felt very markedly in spectroscopic work in a way that hardly needs explanation. If the slit of a spectroscope, put on at the eye-end, is adjusted to be in the focus for H_β light, the circle of aberration on the slit for H_ϵ light is so considerable that but a very small percentage of H_ϵ light gets into the spectroscope. To obviate this difficulty in a way that would in other ways be advantageous, I have had a simple lens made, which, being set in the cone of rays converging from the object-glass of the equatorial to the focus at about 5 feet from that focus, should, by being chromatically uncorrected, just correct the over-corrected object-glass. In this way the separation of the H_β and H_ϵ foci is reduced from 1·5 inches to about two-tenths of an inch, and, but for some mistake made in the working of the lens, the correction would have been more satisfactory even than it is, and I hope shortly to have the more perfect correction made.

The focal length of the combination is shorter by about 18 inches than that of the object-glass alone. It is necessary, therefore, to arrange that the collimator of the spectroscope is

pushed up into the equatorial tube, and space is thus economised and strength gained; and the alteration of ratio of focal length to aperture is one which only brings convenience with it. The correction thus obtained gives very satisfactory results in spectroscopic work.

In having the lens made I intended also to see whether the resulting image could be enlarged by an enlarging camera attached to the equatorial, and had hoped that satisfactory enlargements of planets might thus be obtained, inasmuch as in such work the field is small.

I have made several attempts to photograph *Jupiter*, and have hitherto got results that do not satisfy me. The failure I attribute in part to the difficulty of the subject—the detail is very fine—in part to unfavourable atmospheric conditions, and in part to the imperfection of the correcting lens. I have pleasure in exhibiting to the Society a slide showing the sort of result obtained. In order to test the performance of the enlargement apparatus on other objects, and for the sake of being able more easily to focus the camera, I have taken some enlargements of lunar craters with the same arrangement. Of these also I exhibit slides. The plates on which the originals were taken are Edwards's instantaneous isochromatic; a light yellow glass was used as screen, and the enlargement of the corrected image is sixfold.

The Star Cluster 3315 (*Cape Observations*).

By H. C. Russell, B.A., F.R.S.

The remarkable discovery by MM. Henry of a nebulous background to the *Pleiades* induced me to experiment with the same object in view on the finest of our southern star clusters, which Herschel describes as "the most brilliant object of the kind I have ever seen"; "a glorious cluster of immense magnitude, being at least two fields each way"; and in another place (two or three fields each way), "the stars are 8, 9, 10, and 11 magnitudes, but chiefly of the tenth, of which there must be at least 200."

Three photographs have been taken with a view of finding out if there existed any nebulous light amongst the stars of this magnificent cluster. The first was taken on 1893 April 11, and was exposed in the star camera 7½ hours. On it there is not the slightest sign of any nebulous background, although the plate has recorded in the square degree in which the cluster stands no fewer than 12,702 stars. The second was taken on April 12, and was exposed for 6¾ hours. The night was better than that of the 11th, and as a consequence the plate shows 14,551 stars in the same square degree, and on this also there is

no sign of nebulous background. The third was taken April 23, and it was exposed for $6^h\ 35^m$, and this also is altogether without nebulous background, although it shows 10,946 stars in the same square degree.*

The photographic plates used were extremely sensitive, so much so that seven hours' exposure on them would be equivalent to at least ten hours on the plates in use two years since. I think, therefore, that we may assume that there is no nebulous background to the star cluster H 3315 at all approaching that in the *Pleiades* in brilliance. This cluster appears to the unaided eye as a conspicuous white spot following the nebula about *η Argûs*, and it covers a space about equal to one square degree. It is in R.A. $11^h\ 2^m$, Decl. 58° 9′ S. The *réseau* lines on the photograph enclose spaces 5 minutes of arc each way.

[Slide 10 shows this cluster as photographed here with the star camera, and slide 9 its relation in position to *η Argûs*. If No. 9 numbered corner be held as upper right-hand corner the top is north and the left the following side, and the cluster follows the nebula about one inch, and a little north.]

1894 *February* 2.

A Seconds Contact-Maker for Astronomical Clocks.

By H. C. Russell, B.A., F.R.S.

The difficulty in getting good seconds contacts from astronomical clocks, owing to irregularities due to errors in the spacing of the escape wheel and the faulty methods of contact used, has induced me on several occasions to try and get some attachment to the pendulum that would do the work. Invariably I have been unsuccessful in the search for a good working device, until in July last it occurred to me that if a wheel were attached to the pendulum rod it might be made to roll over a spring and press it down to contact without *any friction except that on the* axis of the wheel. The idea looked promising, and I had one made, which after several months' trial is good enough to publish, since it is likely to be useful to others.

The design is so simple that with the diagram herewith (Plate 7) little explanation is required.

First it will be seen that the contact is made through the medium of a very light wheel attached to the pendulum, which

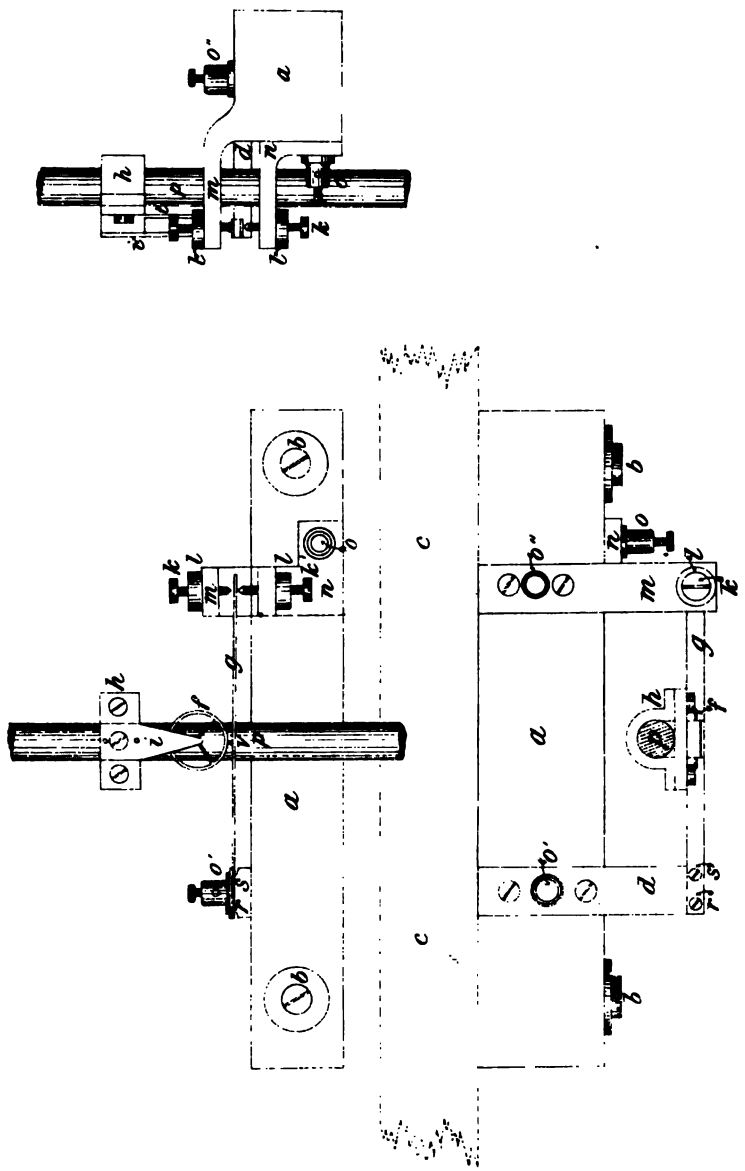
* It may be mentioned that a count of the stars in the same space (1°) in the negative taken with the portrait camera (slide No. 9) of this object, and exposed for eight hours, shows 1,355, or only one-tenth of the number shown on the negative taken with the star camera on 1893 April 12.

at each swing, rolls over a little bridge on the spring and depresses it to make contact. This wheel is the plain balance wheel taken out of a watch, and it therefore has pivots in which friction has been reduced to a minimum. It is also obvious from the arrangement of these parts that after the pendulum passes the centre the recoil of the spring by pressing against the retreating wheel gives a slight impulse to the pendulum, and so restores a part of the work done in depressing it.

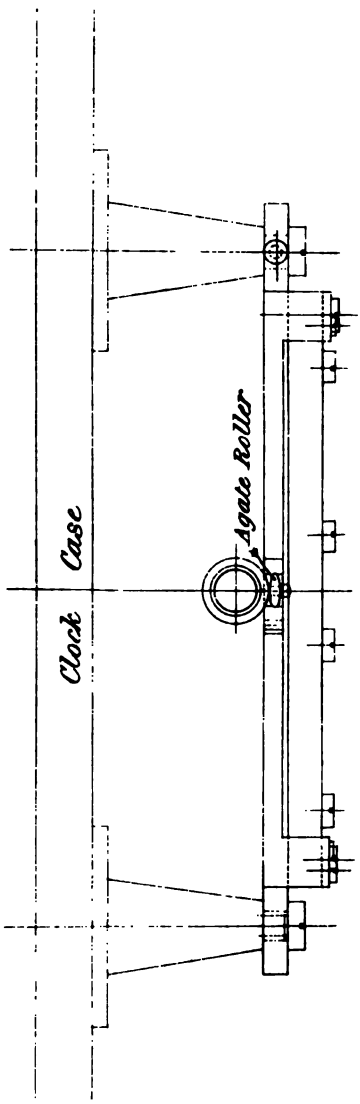
The question of importance is, How much does such a contact reduce the arc of the pendulum? The minimum effect I have not yet determined, but I have found that the maximum effect—which is produced by using a current of six volts, or strong enough to occasionally fuse the platinums together, unless a considerable tension is put on the contact spring—does not reduce the arc of the pendulum any more than the old tilt-hammer contact did when working at its best. Such a current is, of course, quite unnecessary, and by reducing it the strength of the contact spring may be proportionately reduced, and with it the work the pendulum has to do, and the demand therefore made on the clock is far less than that required to work either the tilt-hammer contact or that in which two springs are pressed together by the clock escape-wheel, or another wheel on the same axis.

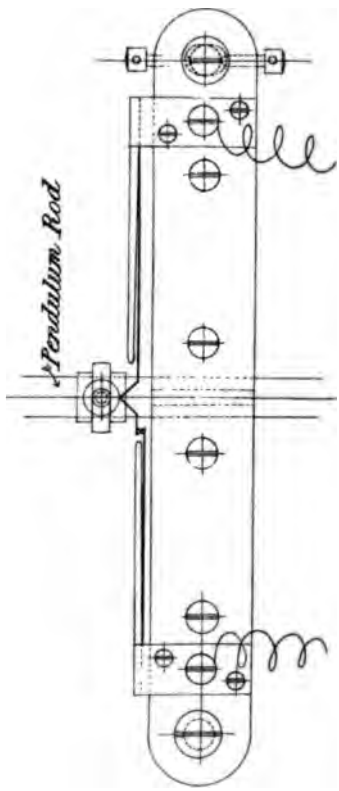
It is a convenience to have the contact-maker placed where it can be seen and cleaned, and especially such an arrangement as this, which can be used either as a make or a break circuit; for to make it a break circuit all that is necessary is to move the wire from one binding screw o to the other o''.

Turning now to the diagram, the attachment on the pendulum rod h is placed about fourteen inches above the top of the pendulum bob—it may be anywhere, but this is the most convenient place—i and t carry the (balance) wheel f; the other parts are attached to a piece of hard wood $a\ a\ a$, which in turn is screwed on to the back of the clock case $c\ c$ by the screws $b\ b$. The bracket piece d is screwed on to a, and carries a binding screw o' and the spring g, which is attached to it by the screws r and s. Under these screws the spring is made thicker, so that it can be screwed in different positions on the rounded base on which it rests, and so adjust the tension of the spring g. Between the steel bar v on g and the screw s, g is filed away as much as possible, to make it easily bent down for contact. At the point where g rests upon k and k' it is coated with platinum, and both screws are tipped with the same metal. The bracket m carries the upper contact screw k and the binding screw o'', while n carries the lower contact screw k' and the binding screw o; $l\ l$ are locking nuts to keep $k\ k'$ in their places; p is the pendulum rod, shown at rest. The attachment h on the pendulum was made much lighter than it is shown in the diagram; the same remark applies to the spring g, which is made of bronze, 0·008 inch



Seconds Contact-maker for Clocks.





Electrical Contact for Clock

thick. In other respects the diagram shows the several parts of the size they were actually made.

Observatory, Sydney:
1893 *December* 20.

P.S.—The necessary break in the circuit to leave out the 60th second is made by a wheel on the escape-wheel axis, which has only one tooth, and this tooth lifts a small tilt-hammer arrangement once a minute and breaks circuit for one second.

[*Note by the Editors.*—When the above paper was read to the meeting on 1894 March 9, it was remarked that similar devices had been used before. Messrs. T. Cooke & Sons, of York, have shown in a sketch (Plate 8) an arrangement of the kind made by them some years back. As it does not appear certain, however, that any account of such an arrangement has yet been published, the Council deemed it advisable to publish Mr. Russell's paper, together with Messrs. Cooke's sketch.]

Occultation of a Virginis observed at Dunsink, 1894 March 22.
By Professor Arthur A. Rambaut, M.A., Sc.D.

The occultation of *a Virginis*, which took place on the morning of Good Friday, was observed here by my assistant, Mr. Lyster, and myself. I used the 12-inch refractor, with a power of 300, and recorded the times of disappearance and reappearance electrically on the chronograph. Mr. Lyster was stationed at the 5-inch guiding telescope, attached to the "Roberts" photographic equatorial, carrying a power of 100, and noted the times by direct comparison with an Arnold clock in the dome. The error and rate of this clock were determined by comparing it with a chronometer which was also compared with the Dent sidereal clock.

At the time of disappearance we were enveloped in a dense fog, which completely obscured *Spica* and *Saturn* (which was in the neighbourhood) from the naked eye, but by the time the star was due to reappear the fog had almost entirely cleared away.

To me the star seemed to disappear instantaneously at $15^h\ 31^m\ 46^s{\cdot}97$ local sidereal time. This was, of course, at the bright limb.

At emergence I put a note to the effect that "reappearance was not quite instantaneous, perhaps a tenth of a second before full brilliance was attained." The time noted as that of reappearance corresponds to the first gleam of light sufficient to attract my attention. This occurred at $16^h\ 41^m\ 24^s{\cdot}91$ local sidereal time.

Mr. Lyster reports that both disappearance and reappearance seemed to him to occur instantaneously; the former at $15^h\ 31^m\ 45^s{\cdot}9$, and the latter at $16^h\ 41^m\ 24^s{\cdot}6\pm$, local sidereal time.

Dunsink Observatory, Co. Dublin:
1894 *March* 27.

Observations of Denning's Comet (a 1894), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log Factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log Factor of Parallax.	No. of Comps.	Appt. R.A.	Appt. N.P.D.	Comp. ✱
1894. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
Mar. 27 8 20 46	A. C.	−1 20·49	0·00	9·1467	−6 4·9	0·0	0·4945	3	9 58 12·56	58 17 48·2	*a*
27 8 28 20	„	−1 52·58	0·00	9·1040	+2 44·9	0·0	0·4905	6	9 58 13·32	58 17 54·4	*b*
31 8 50 35	„	−2 12·85	0·00	8·9045	−1 39·5	0·0	0·5229	7	10 12 28·29	60 29 49·1	*c*
Apr. 2 8 43 52	„	−2 22·02	0·00	8·9413	−0 59·5	0·0	0·5439	6	10 19 0·72	61 34 20·2	*d*
2 8 40 1	„	−5 5·00	0·00	8·9792	−3 38·3	0·0	0·5449	5	10 19 0·35	61 34 15·6	*e*
3 10 16 24	L.	+0 52·55	0·00	8·8874	+4 43·1	0·0	0·5511	2	...	...	*f*
3 10 16 24	„	+0 19·24	0·00	8·8874	−6 22·8	0·0	0·5511	2	10 22 22·47	62 8 25·7	*g*
6 8 42 27	A. C.	−2 3·06	0·00	8·9211	+0 3·4	0·0	0·5780	5	10 31 8·49	63 40 57·6	*h*
9 10 40 34	„	−1 18·00	0·00	9·1063	−1 4·2	0·0	0·6092	4	10 39 43·75	65 16 1·5	*i*
9 10 40 34	„	−1 18·72	0·00	9·1063	−1 43·7	0·0	0·6092	4	10 39 43·89	65 16 2·1	*k*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the errors of inclination of the wires, and for the motion of the comet.

On April 2 a slight haze and the close proximity of the 9·5 magnitude star B.D. + 28° 1877 to the comet made observation of the latter very difficult. The apparent place of the star on April 2 was R.A. $10^h\ 18^m\ 59^s{\cdot}35$, N.P.D. 61° 35′ 21″·9 (authority, *Bonn Observations*, vol. vi.), and it was estimated that the comet was in conjunction with it in R.A. at $8^h\ 31^m$ G.M.T.

On April 6 the night was hazy and the comet never well defined.

The initials L. and A.C. are those of Mr. Lewis and Mr. Crommelin respectively.

Comparison Stars.

	Star's Name.	R.A., 1894 o.	N.P.D., 1894.o.	Authority.
		h m s	c ′ ″	
a	W.B. (2) IX., 1211	9 59 30·95	58 23 54·1	Leiden Ast. Gesell. Zones, 163, 278, and Pulkova Catalogue, 1875.
b	W.B. (2) IX., 1234, 1235	10 0 3·80	58 15 10·5	Leiden Ast. Gesell. Zones, 41, 286.
c	W.B. (2) X., 246	10 14 39·07	60 31 28·4	Paris Catalogue, 1860 and 1875.
d	B.D. + 28°, 1879	10 21 20·69	61 35 19·0	Bonn Observations, vol. vi.
e	W.B. (2) X., 439	10 24 3·29	61 37 52·9	Weisse's Bessel (2) and Lalande.
f	B.D. + 28°, 1882	10 21 29	62 5	Bonn Observations, vol. iv.
g	W.B. (2) X., 386	10 22 1·20	62 14 47·7	Weisse's Bessel (2).
h	W.B. (2) X., 619, 620	10 33 9·54	63 40 52·5	Paris Catalogue, 1875.
i	B.D. + 24°, 2269, 1st *	10 40 59·77	65 17 3·4	Berlin Ast. Gesell. Zones, 217, 225, 236.
k	„ 2nd *	10 41 0·63	65 17 43·5	Berlin Ast. Gesell. Zones, 236, 245, 249.

Note.—*a* is the double star Σ 1406; the mean of the places for the components has been used.

Observations of Comet a 1894 (*Denning*). By William E. Plummer.

The following observations of Denning's Comet have all been made by the method of transits over a pair of wires, inclined at an angle of 45° to the meridian, the comet not being sufficiently bright to permit the use of a filar micrometer on the equatorial of the Liverpool Observatory. In the column "Observer" the letters P. and S. refer to Mr. Plummer and Mr. Skinner respectively.

Greenwich Mean Time of Observation.				☄−✱ R.A.	Apparent R.A. of ☄.	☄−✱ Declination.	Apparent Declination of Comet.	No. of Transits.	Observer.	Log. Fact. of Parallax a	Log. Fact. of Parallax δ	Star of Comp.
	h	m	s	m s	h m s	′ ″	° ′ ″					
Mar. 27	10	2	49·8	−1 37·60	9 58 28·37	− 4 46·50	+31 40 4·9	10	P.	8·3539	0·5059	*a*
	10	14	20·7	−1 3·55	9 58 29·55	+ 3 48·8	+31 39 45·7	10	P.	8·6563	0·5077	*b*
	10	55	0·5	−1 0·48	9 58 32·62	+ 3 23·5	+31 39 20·4	5	S.	8·9258	0·5133	*b*
28	9	39	45·8	+1 54·22	10 2 6·10	− 7 47·0	+31 7 34·3	10	P.	8·2291*n*	0·5161	*c*
	9	39	45·8	− 23·08	10 2 6·40	+ 0 26·9	+31 7 24·3	10	P.	8·2291*n*	0·5161	*d*
	9	55	52·4	− 20·62	10 2 8·86	+ 14·5	+31 7 11·9	8	S.	8·0863	0·5162	*d*
29	9	7	49·9	− 6·72	10 5 36·29	...	...	9	P.	8·8648*n*	...	*e*
	9	4	3·6	...	...	− 4 44·0	+30 35 33·0	8	P.	...	0·5320	*e*
	9	24	14·4	− 3·99	10 5 39·02	− 5 14·1	+30 35 2·9	6	S.	8·6436*n*	0·5300	*e*
Mar. 30	9	15	14·3	−1 8·48	10 9 7·00	+12 10·0	+30 2 29·9	10	P.	8·7696*n*	0·5389	*f*
	9	23	19·5	−1 59·88	10 9 8·32	− 2 40·7	+30 2 16·5	10	P.	8·6479*n*	0·5376	*g*
	9	44	14·0	−1 4·30	10 9 11·18	+11 27·7	+30 1 47·6	6	S.	7·8491*n*	0·5355	*f*
Apr. 1	8	1	4·0	+ 48·48	10 15 40·96	− 4 6·8	+28 58 58·7	10	P.	9·2653*n*	0·5856	*h*
	8	1	4·0	+ 8·90	10 15 40·79	− 5 15·2	+28 59 0·2	10	P.	9·2653*n*	0·5856	*i*

March 27.—The comet ill defined and the observation not thought very exact.
March 28.—The comet seen much better; a definite point seen in the comet to which the observations refer.
March 29.—An observation of declination rejected from discordance.
March 30.—The observation difficult, owing to very brilliant aurora. The sky was not dark.

Mean Places of Stars of Comparison.

Star's Designation or Authority.	Mean Rel. 1894.0	Corr. to Apparent Equinox.	Mean Declination 1894.0.	Corr. to Apparent Equinox.	Letter of Reference.
	h m s	s	° ′ ″	″	
Leiden Zones, 41, No. 37	10 0 3·87	+2·10	+31 44 50·4	+1·0	*a*
„ „ 163, No. 126	9 59 31·01	+2·09	+31 35 55·9	+1·0	*b*
„ „ 163, No. 127	10 0 9·82	+2·06	+31 15 20·4	+0·9	*c*
„ „ 172, No. 25	10 2 27·40	+2·08	+31 6 56·6	+0·8	*d*
Washington Zones, No. 4328 Leiden Zones, 39, No. 60	10 5 40·93	+2·08	+30 40 16·5	+0·5	*e*
Greenwich 864 Cat. No. 1243 Glasgow Cat. No. 2658	10 10 13·42	+2·06	+29 50 19·8	+0·1	*f*
Leiden Zones, 41, No. 46	10 11 6·13	+2·07	+30 4 57·1	+0·1	*g*
Bonn Zones, +29°, No. 2032	10 14 50·43	+2·05	+29 3 5·8	−0·3	*h*
Paris Catalogue, No. 12665	10 15 29·84	+2·05	+29 4 13·7	−0·3	*i*

Liverpool Observatory:
1894 *April* 12.

Note on the Computation of the Brightness of the Planets, with some Ephemerides for Observations of the Brightness of Mercury. By A. Marth.

In the *Nautical Almanacs* for the years 1835 to 1857 the times of the greatest brilliancy of *Venus* are predicted to the minute. Wondering at this precision in the prediction of such an occurrence, I tried, by computing a number of instances, to find out what hypothesis could have been adopted in the computations. The predicted times were found to be within a couple of days of the times computed upon the ordinary assumption that the diminution of brightness due to the defect of illumination depends simply on the proportion of the unilluminated portion to the whole of the disc; but what modification of this assumption had been introduced, or how the apparent precision had been obtained, I failed to detect. When, in 1853, I got the opportunity of making inquiries at the *Nautical Almanac* office, I learnt that nothing was known there about any hypothesis, but that the predicted times were very easily computed to a minute, as they were merely the times when the distance of *Venus* from the Earth reached a certain value. As this value had obviously been deduced upon the ordinary assumption, but by neglecting the eccentricities of the orbits, I pointed out the illusory character of the predicted times, and recommended to give in future merely the day, but the right day. Since the distances of *Venus* from the Sun and from the Earth r and Δ and the distance of the Sun from the Earth were given in the *N. A.*, the light-ratio of *Venus* could be found from them, without actually computing the phase angle v or the angle at *Venus* between r and Δ. For, assuming that the Sun lights up just one-half of the surface of the planet, or disregarding the small zone of doubtful breadth beyond, the light-ratio would be

$$\frac{\cos^2 \frac{1}{2} v}{r^2\Delta^2}, \text{ or } \frac{(r+\Delta)^2 - R^2}{r^2\Delta^2};$$

so that by computing this value, or, if preferred,

$$\frac{(r+\Delta+R)}{r^2\Delta^2}\frac{(r+\Delta-R)}{},$$

for some days near the time, the day during which this value reached a maximum would be the right one. This recommendation was adopted in the *N. A.* for 1858, and the computations have been made since in this manner; but from 1875 onwards the hour of the greatest brilliancy has again been inserted.

The logarithm of the light-ratio (0·4 of which represents

a difference in brightness of one star-magnitude), according to the foregoing formula, the phase angle v, the angle e at the Earth between R and Δ, and the brightness of the planet according to Professor G. Müller's empirical formula for some days about the times of this year's maxima are the following, the magnitudes for the days in January having been already given by Müller himself in his paper "Ueber den grössten Glanz der Venus," *Astron. Nachr.*, vol. 132, p. 300:—

Greenwich Noon. 1894.	log. $\frac{(r+\Delta)^2-R^2}{r^2\Delta^2}$	v	e	Müller's Mag.
		°	°	m
Jan. 9	1·07861	115·75	41·24	−4·3776
10	·07942	116·81	40·78	−4·3798
11	·07973	117·89	40·29	−4·3809
12	·07949	118·99	39·78	−4·3809
13	·07864	120·12	39·24	−4·3802
14	1·07714	121·28	38·68	−4·3782
Mar. 21	1·04501	120·92	38·40	−4·297
22	·04565	119·79	38·93	−4·297
23	·04570	118·68	39·43	−4·296
24	1·04519	117·60	39·90	−4·294

The interesting results which Professor Müller has deduced from his own measurements of the brightness of *Mercury* (in vol. viii. of the *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, and in his paper "Ueber die Lichtstärke des Planeten Mercur," in the *Astron. Nachr.* vol. 133, p. 47 ff.) render it very desirable that these results should be tested and the measurements, if possible, extended over a greater range of the phase angle. The smallest angular distance of *Mercury* from the Sun, at which Müller has succeeded in getting some measures, is 14°·7 (on February 14, 1881, in zenith distance 85°·1, the comparison being made with *Venus*), so that it will be feasible to extend the range, even if the difficulties in getting good measures nearer to the Sun cannot be surmounted. This may be seen by looking over the following ephemerides, which give the phase angle v, the angle e at the Earth between *Mercury* and the Sun, and the brightness of *Mercury* expressed in star magnitudes and computed (I.) by Müller's (second) empirical formula, and (II.) upon the makeshift assumption that the alteration of magnitude due to the defect of illumination is just double of what it should be according to the usual assumption, or, what amounts to the same, that the light-ratio is

$$\frac{\cos^4\frac{1}{2}v}{r^2\Delta^2} \quad \text{instead of} \quad \frac{\cos^2\frac{1}{2}v}{r^2\Delta^2}.$$

There is no justification for this makeshift assumption except the empirical one that, within the range of the phase angle between

50° or 60° and 120°, it gives no greater discrepancies from the measured magnitudes than Müller's own formula, while outside this range the resulting magnitudes diverge rapidly, so that their comparison indicates sufficiently that for the recognition of the true hypothesis measurements over a considerably extended range are required. For the sake of the comparison the magnitudes derived from

$$\text{I.} = 5 \log \left(\frac{r\Delta}{r_0}\right) - 0{\cdot}901 + 0{\cdot}02838\,(v-50°) + 0{\cdot}0001223\,(v-50°)^2,$$

wherein $\log \frac{1}{r_0} = 0{\cdot}41218$

are carried some 10° beyond the limits of the phase angle within which they are valid. The magnitudes given by II. are

$$\text{II.} = 5 \log \left(\frac{r\Delta}{r_0}\right) - 1{\cdot}25 + 10 \log \sec \tfrac{1}{2}v.$$

The angles v and e are conveniently computed in the following way:—

In the plane triangle formed by $r\Delta R$, in which the angle v is opposite to R, and e opposite to r, we have

$$\cos v = \frac{r^2+\Delta^2-R^2}{2r\Delta} \text{ and } \cos e = \frac{R^2+\Delta^2-r^2}{2R\Delta}.$$

Hence
$$\tan^2 \tfrac{1}{2}v = \frac{1-\cos v}{1+\cos v} = \frac{R+r-\Delta}{R+r+\Delta} \cdot \frac{\Delta+R-r}{\Delta-(R-r)};$$
$$\tan^2 \tfrac{1}{2}e = \frac{1-\cos e}{1+\cos e} = \frac{R+r-\Delta}{R+r+\Delta} \cdot \frac{\Delta-(R-r)}{\Delta+R-r}.$$

Therefore, by computing

$$\tan^2 \tfrac{1}{2}\gamma = \frac{\Delta}{R+r} \text{ and } \tan^2 \tfrac{1}{2}\nu = \frac{R-r}{\Delta},$$

we get

$$\tan^2 \tfrac{1}{2}v = \frac{\cos \gamma}{\cos \nu} \text{ and } \tan^2 \tfrac{1}{2}e = \cos \gamma \cdot \cos \nu,$$

and have also for check or control

$$r \sin v = R \sin e.$$

If $r > R$, as in the case of the asteroids, the corresponding formulæ are derived from the foregoing by exchanging v and r with e and R, so that, by computing

$$\tan^2 \tfrac{1}{2}\gamma = \frac{\Delta}{r+R} \text{ and } \tan^2 \tfrac{1}{2}\nu = \frac{r-R}{\Delta},$$

we get

$$\tan^2 \tfrac{1}{2}e = \frac{\cos \gamma}{\cos \nu} \text{ and } \tan^2 \tfrac{1}{2}v = \cos \gamma \cdot \cos \nu.$$

Mercury.

Greenwich Noon. 1894.		v	e	Magnitude. I.	II.
		°	°		
May	29	36·11	10·70	...	−0·95
	30	39·87	11·80	−1·10	−0·90
	31	43·52	12·86	−1·00	−0·85
June	1	47·05	13·84	−0·90	−0·79
	2	50·46	14·86	−0·80	−0·73
	3	53·76	15·80	−0·70	−0·66
	4	56·94	16·70	−0·60	−0·60
	5	60·00	17·56	−0·51	−0·53
	6	62·95	18·37	−0·42	−0·46
	7	65·80	19·14	−0·33	−0·39
	8	68·55	19·87	−0·24	−0·33
	9	71·20	20 55	−0·16	−0·26
	10	73·77	21·19	−0·08	−0·19
	11	76·26	21·79	0·00	−0·13
	12	78 68	22·34	0·07	−0·06
	13	81·03	22·84	0 14	0·00
	14	83·33	23·30	0·21	0·07
	15	85·57	23·71	0·28	0·13
	16	87·77	24·08	0 34	0·20
	17	89·93	24·40	0·40	0·26
	18	92·06	24·67	0 46	0 33
	19	94·17	24·89	0·52	0 39
	20	96·26	25·07	0·58	0·46
	21	98·33	25·19	0·64	0·52
	22	100·40	25·26	0·69	0·59
	23	102·47	25·28	0·75	0·66
	24	104·55	25·24	0 80	0·73
	25	106·65	25·15	0·86	0·81
	26	108·76	25 00	0 91	0·89
	27	110·89	24·79	0·97	0·97
	28	113·05	24·51	1·02	1·06
	29	115·24	24·18	1·08	1·16
	30	117 47	23·78	1·14	1·26
July	1	119·75	23·32	1·20	1·37
	2	122·08	22·79	1·27	1·49
	3	124·46	22·19	1·34	1·62
	4	126 90	21·52	1·41	1·77
	5	129 39	20·77	1·48	1·93
	6	131·96	19·96	1·56	2·10

Greenwich Noon. 1894.		v	e	Magnitude. I.	II.
		°	°		
Aug.	1	132·68	15·93	1·38	1·95
	2	128·74	16 66	1·23	1·65
	3	124·76	17·30	1·08	1·38
	4	120·74	17·84	0·93	1·12
	5	116·67	18·27	0·79	0·89
	6	112·54	18·60	0·64	0·67
	7	108·35	18·83	0 50	0·47
	8	104·10	18·95	0 36	0·29
	9	99·80	18·97	0·22	0·12
	10	95·44	18·89	0·08	−0·04
	11	91·02	18·71	−0·05	−0·19
	12	86·55	18·44	−0·18	−0·32
	13	82·03	18·08	−0·30	−0·44
	14	77·47	17·64	−0·43	−0·55
	15	72 87	17·12	−0·55	−0·65
	16	68·26	16·52	−0·66	−0·74
	17	63·65	15·85	−0 76	−0·81
	18	59·06	15·12	−0·86	−0·87
	19	54·51	14·33	−0·95	−0·92
	20	50·02	13·49	−1·03	−0·96
	21	45·61	12·62	−1·11	−0·99
	22	41·31	11·72	−1·18	−1·00
	23	37·12	10·78	−1·24	−1·01
Nov.	17	130·69	13·73	0·97	1·46
	18	124·06	15·12	0·75	1·02
	19	117·71	16·32	0·55	0·68
	20	111·65	17·33	0·39	0·40
	21	105·89	18·16	0·24	0·18
	22	100·44	18 81	0·11	0·01
	23	95·28	19·32	0·01	−0·12
	24	90·41	19·70	−0·08	−0·22
	25	85·82	19·95	−0·16	−0·30
	26	81·49	20·10	−0·22	−0·36
	27	77·42	20·16	−0·27	−0·40
	28	73·59	20·13	−0·31	−0·42
	29	69·98	20·04	−0·35	−0·44
	30	66·58	19·88	−0·38	−0·45
Dec.	1	63·38	19·67	−0·40	−0·44
	2	60·36	19·42	−0·41	−0·44

Greenwich Noon.		v	e	Magnitude. I.	II.
	1894.	°	°		
Dec.	3	57·51	19·12	−0·43	−0·43
	4	54·81	18·80	−0·44	−0·41
	5	52·26	18·44	−0·45	−0·39
	6	49 85	18·06	−0·45	−0·37
	7	47·56	17 66	−0·45	−0·35
	8	45·39	17·25	−0·46	−0·33
	9	43·32	16·82	−0·46	−0·30
	10	41·35	16·37	−0·46	−0·28
	11	39·46	15·92	−0·46	−0·26
	12	37 66	15·45	...	−0·24
	13	35·93	14·97	...	−0·21
	14	34·27	14·49	...	−0·19
	15	32·68	14·01	...	−0·17
	1895.				
Jan.	26	31·64	11·27	...	−0·67
	27	34·41	11·96	...	−0·70
	28	37·33	12·64	...	−0·73
	29	40 42	13 31	−0·94	−0·75
	30	43·68	13·97	−0·92	−0·78
	31	47 13	14·60	−0 90	−0 79
Feb.	1	50·76	15·21	−0·87	−0·80
	2	54·58	15·79	−0·84	−0·81
	3	58·59	16·33	−0·79	−0·80
	4	62·80	16·82	−0·74	−0·78
	5	67·21	17·25	−0·68	−0·75
	6	71·81	17·61	−0·61	−0·71
	7	76·60	17·90	−0·52	−0·64
	8	81·57	17·09	−0·42	−0·56
	9	86 71	18·17	−0·31	−0·46
	10	92·01	18 14	−0·19	−0·33
	11	97·44	17·99	−0·05	−0·17
	12	103·00	17·70	0·10	0 02
	13	108·67	17·26	0·26	0·24
	14	114·43	16·66	0·44	0 50
	15	120·25	15·91	0·63	0·81
	16	126·12	14·99	0·84	1·18
	17	132 02	13 91	1·06	1·61
	18	137·90	12·68	...	2·11
	19	143·73	11·31	...	2 70

Col. Cooper's Observatory,
Markree, Colloney, Ireland.

Ephemeris for Physical Observations of Mars, 1894. By A. Marth.

Greenwich Noon.	Position Angle of δ's Axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Apparent Diameter.	ϱ	Q	E	Brightness in Star Mag. I.	Brightness in Star Mag. II.
1894.	°	°	°	″	″	°	°		
May 31	341·89	307·68	−23·64	8·82	1·35	246·97	46·05	−0·25	0·25
June 2	341·12	288·01	23·70	8·93	1·37	·87	46·18	−0·28	0·22
4	340·36	268·34	23·74	9·04	1·40	·78	46·30	−0·31	0·20
6	339·62	248·68	23·77	9·15	1·42	·71	46·41	−0·34	0·17
8	338·89	229·02	23·79	9·27	1·45	·65	46·51	−0·37	0·14
10	338·17	209·37	−23·79	9·39	1·47	246·60	46·60	−0·39	0·11
12	337·47	189·73	23·77	9·51	1·49	·57	46·69	−0·42	0·08
14	336·78	170·10	23·74	9·63	1·51	·55	46·77	−0·45	0·06
16	336·11	150·47	23·69	9·76	1·54	·54	46·83	−0·48	0·03
18	345·45	130·86	23·63	9·89	1·56	·54	46·89	−0·51	0·00
20	334·81	111·25	−23·56	10·02	1·59	246·56	46·94	−0·54	−0·03
22	334·19	91·65	23·47	10·15	1·61	·59	46·97	−0·57	−0·06
24	333·59	72·07	23·37	10·28	1·64	·63	47·00	−0·60	−0·09
26	333·00	52·50	23·26	10·41	1·66	·68	47·01	−0·63	−0·12
28	332·43	32·95	23·13	10·56	1·68	·75	47·02	−0·66	−0·15
30	331·85	13·41	−22·99	10·71	1·70	246·83	47·01	−0·69	−0·18
July 2	331·35	353·88	22·85	10·86	1·73	246·92	46·98	−0·72	−0·21
4	330·83	334·37	22·69	11·01	1·75	247·02	46·95	−0·76	−0·25
6	330·33	314·88	22·52	11·16	1·77	247·13	46·90	−0·79	−0·28
8	329·86	295·40	22·34	11·32	1·79	247·25	46·84	−0·82	−0·31
10	329·40	275·94	−22·16	11·48	1·81	247·38	46·76	−0·85	−0·34
12	328·96	256·50	21·96	11·65	1·83	247·52	46·66	−0·88	−0·38
14	328·54	237·09	21·75	11·82	1·85	247·67	46·55	−0·92	−0·41
16	328·14	217·69	21·54	11·99	1·86	247·82	46·42	−0·95	−0·44
18	327·76	198·31	21·33	12·16	1·88	247·99	46·28	−0·98	−0·48
20	327·40	178·96	−21·11	12·34	1·89	248·17	46·12	−1·02	−0·51
22	327·05	159·63	20·88	12·53	1·91	248·35	45·94	−1·05	−0·55
24	326·73	140·32	20·64	12·72	1·92	248·54	45·74	−1·08	−0·58
26	326·42	121·04	20·41	12·91	1·93	248·74	45·52	−1·12	−0·62
28	326·13	101·78	20·17	13·11	1·94	248·94	45·28	−1·15	−0·66
30	325·86	82·55	−19·93	13·31	1·95	249·15	45·01	−1·19	−0·69
Aug. 1	325·60	63·35	19·69	13·52	1·96	249·37	44·72	−1·23	−0·73
3	325·36	44·18	19·45	13·73	1·96	249·59	44·41	−1·26	−0·77
5	325·14	25·04	19·21	13·95	1·96	249·81	44·07	−1·30	−0·81

Greenwich Noon.	Position Angle of ♂'s Axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Apparent Diameter.	ρ	Q	E	Brightness in Star Mag. I.	Brightness in Star Mag. II.
1894.	°	°	°	″	″	°	°		
Aug. 7	324·93	5·93	18·98	14·17	1·96	250·04	43·70	−1·33	−0 85
9	324·74	346·85	−18 75	14·40	1·96	250 27	43·30	−1·37	−0 89
11	324·57	327·81	18·52	14·63	1·95	250·51	42·87	−1·41	−0 93
13	324·41	308·80	18 30	14·87	1·95	250·75	42·42	−1 45	−0·97
15	324·26	289·82	18·08	15·11	1·94	250 99	41·93	−1·48	−1·01
17	324·12	270·88	17·87	15·36	1·92	251·23	41·41	−1·52	−1·05
19	324·00	251·98	−17·66	15·61	1·90	251·47	40·85	−1·56	−1·09
21	323 89	233·12	17·47	15·87	1·88	251·71	40 26	−1·60	−1·14
23	·79	214·30	17·29	16·13	1·85	251·95	39 63	−1·64	−1·18
25	·70	195·52	17 12	16·40	1·82	252·19	38 96	−1·68	−1·23
27	·62	176·78	16·96	16·67	1·79	252·43	38 25	−1·72	−1·27
29	323 55	158 09	−16·81	16·95	1·75	252·67	37·49	−1·76	−1·32
31	·49	139·45	16 68	17·23	1·71	252 91	36 68	−1·79	−1·36
Sept. 2	·44	120·86	16·57	17·51	1 66	253 15	35·83	−1 83	−1·41
4	·39	102·32	16·47	17 79	1·60	253 38	34·93	−1 87	−1·46
6	·35	83·83	16·40	18·08	1·54	253·01	33 98	−1·91	−1 50
8	323·32	65·38	−16 34	18 37	1·48	253·84	32·98	−1·95	−1·55
10	·30	46 99	16·30	18 65	1·41	254·08	31·93	−1 99	−1·60
12	·28	28·65	16·28	18 93	1·34	254·31	30·83	−2·02	−1·64
14	·27	10·37	16 28	19 21	1·26	254·54	29·67	−2 06	−1 69
16	·26	352 15	16·30	19·48	1·18	254 78	28·45	−2 09	−1·74
18	323 26	333 98	−16·35	19·75	1·09	255 02	27·18	−2·13	−1·78
20	·27	315·86	16·42	20·01	1·00	255·27	25·85	−2·16	−1·83
22	·28	297·80	16·51	20·26	0·91	258 54	24·47	−2·19	−1·87
24	·30	279·80	16·63	20·50	0·82	255·83	23·03	−2·22	−1·92
26	·32	261·86	16·77	20·72	0 72	256·14	21·53	−2·24	−1·96
28	323·36	243·97	−16·93	20·93	0·63	256·50	19·98	−2·27	−2·00
30	·40	226·13	17·11	21 12	0·54	256·91	18 38	−2·29	−2·04
Oct. 2	·45	208·33	17·31	21·28	0·45	257·40	16·74	−2·31	−2·08
4	·51	190·58	17·53	21·42	0·37	258·00	15·05	−2·32	−2·12
6	·57	172·88	17·76	21·53	0·29	258·74	13·33	−2·34	−2·15
8	323·64	155·21	−18·01	21·62	0·22	259·73	11·58	−2·35	−2·18
10	323·72	137·57	18·28	21·67	0·16	261·10	9·80	−2·35	−2·21
12	323·81	119·95	18 55	21 70	0·11	263·10	8·00	−2·35	−2·23
14	323·91	102·36	18·83	21·69	0·06	266·3	6·21	−2·35	−2·26
16	324·02	84·78	19·12	21·65	0·03	272·1	4·44	−2 35	−2·28
18	324·13	67·20	−19·41	21·58	0·013	285·3	2·78	−2·34	−2·30

Greenwich Noon.	Position Angle of δ's Axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Apparent Diameter.	φ	Q	E	Brightness in Star Mag. I.	Brightness in Star Mag. II.
1894.	°	°	°	″	″	°	°		
Oct. 20	324·24	49·63	−19·70	21·47	0·004	324·8	1·60	−2·32	−2·30
22	324·36	32·05	19·99	21·33	0·009	23·8	2·05	−2·31	−2·28
24	324·48	14·46	20 28	21·16	0·02	46·3	3·54	−2·29	−2·23
26	324·61	356·85	20 56	20 97	0·04	54·8	5·23	−2·26	−2·19
28	324·73	339·21	−20·83	20·74	0·08	59·02	6·94	−2·23	−2·14
30	324·85	321·54	21·10	20·49	0·12	61·50	8·65	−2·20	−2·08
Nov. 1	324·96	303 84	21·36	20·22	0·16	63·12	10·33	−2·17	−2 02
3	325·06	286·09	21·60	19·92	0·22	64·24	11·97	−2·13	−1·96
5	325·16	268·30	21·83	19·61	0·27	65·07	13·61	−2·09	−1 90
7	325·25	250 46	−22·04	19·29	0 33	65 68	15·11	−2·04	−1·84
9	325·33	232·56	22·24	18·95	0·39	66·17	16·60	−2·00	−1·77
11	325·39	214·61	22·42	18·60	0·46	66·55	18·04	−1·95	−1·71
13	325·44	196·60	22·59	18·25	0·52	66 86	19·42	−1·90	−1 64
15	325·48	178·54	22·75	17 89	0·58	67·12	20·75	−1·85	−1·58
17	325·50	160·42	−22·89	17 53	0·64	67·34	22·02	−1·80	−1 51
19	325·51	142·25	23·01	17·16	0·70	67·52	23·23	−1·74	−1·44
21	325·50	124·02	23·11	16·80	0·75	67·68	24·39	−1·69	−1·37
23	325·48	105 73	23·20	16·44	0·80	67·82	25·49	−1·63	−1·31
25	325·44	87·38	23 28	16·08	0·85	67·94	26·53	−1·57	−1·24
27	325·39	68·98	−23·34	15·72	0·89	68·05	27·52	−1·52	−1·17
29	325·33	50·53	23·39	15·37	0·93	68·15	28·45	−1·46	−1·11
Dec. 1	325·25	32·03	23·42	15·03	0·96	68·25	29·33	−1·40	−1·04
3	325·17	13·47	23·43	14·69	0·99	68·34	30·16	−1·35	−0·97
5	325·07	354·87	23·43	14·36	1·02	68·43	30·94	−1·29	−0·91
7	324·96	336·22	−23·42	14·04	1·05	68·52	31·17	−1·23	−0·84
9	324·84	317·52	23·39	13 72	1·07	68·61	32·36	−1·17	−0·78
11	324·71	298·79	23·35	13 42	1 09	68·69	33·01	−1·12	−0·72
13	324·58	280 02	23·30	13·12	1·10	68·78	33·61	−1·06	−0·66
15	324·44	261·21	23·23	12·83	1·11	68·87	34·17	−1·01	−0·60
17	324·29	242 36	−23·15	12·54	1·12	68·96	34·70	−0 95	−0·54
19	324·14	223·48	23·05	12·27	1·12	69·05	35·19	−0·90	−0·48
21	323·99	204·56	22·94	12·00	1·12	69·15	35 64	−0·84	−0·42
23	323·84	185·62	22·82	11·75	1·12	69·25	36·06	−0 79	−0·36
25	323·68	166·65	22·69	11·50	1·12	69·36	36·44	−0·74	−0 31
27	323·53	147·65	−22·54	11·25	1·12	69·48	36·79	−0·68	−0 25
29	323·38	128·63	22·38	11·02	1·12	69·60	37·12	−0 63	−0·20
31	323·23	109·58	22·21	10·79	1·11	69·73	37·41	−0·58	−0·14

Greenwich Noon.		Position Angle of ♂'s Axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Apparent Diameter.	q	Q	E	Brightness in Star Mag. I.	Brightness in Star Mag. II.
1895.		°	°	°	″	″	°	°		
Jan.	2	323·08	90·51	−22·03	10·57	1·10	69·86	37·68	−0·53	−0·09
	4	322·94	71·42	21·83	10 36	1·09	69·99	37·93	−0·48	−0·04
	6	322·80	52·31	−21·62	10·15	1·08	70·14	38·15	−0·43	c·01
	8	322·67	33·18	21·40	9·95	1·07	70·30	38·34	−0·38	0·06
	10	322·54	14·03	21·17	9·75	1·06	70 46	38·51	−0·34	0·11
	12	322·42	354·87	20·93	9·57	1·05	70·63	38·66	−0 29	0·16
	14	322·31	335·70	20·67	9 39	1·03	70·80	38 79	−0·24	0·21
	16	322·21	316·51	−20·41	9·21	1·02	70·99	38·90	−0·20	0·25
	18	322·12	297·31	20·13	9·04	1·01	71·18	38 99	−0·15	0·30
	20	322·04	278·10	19·84	8 87	0·99	71·38	39·06	−0·11	0·34
	22	321·97	258·88	19·55	8·71	0·98	71·59	39·12	−0·07	0·39
	24	321·91	239·65	19 24	8 56	0·96	71·81	39·16	−c·02	0·43
	26	321·86	220·41	−18·92	8·41	0·95	72·04	39·18	0 02	0·47
	28	321·83	201·16	18·59	8·26	0·93	72·28	39·19	0·06	0·51
	30	321·81	181·91	18·25	8·12	0·91	72·52	39·18	0·10	0·55
Feb.	1	321·80	162·65	17·90	7·99	0 90	72·78	39 16	0·14	0·59
	3	321·80	143·38	17·55	7·86	0·88	73·04	39·13	0·18	0·63
	5	321·82	124 11	−17·18	7·73	0 86	73·31	39·08	0·22	0·67
	7	321·86	104·83	16·80	7·60	0·85	73·59	39·02	0·26	0·71
	9	321·91	85·55	16·42	7·48	0·83	73·88	38·95	0·29	0 74
	11	321·97	66·26	16·03	7·37	0·82	74·18	38·87	0·33	0·78
	13	322·05	46·97	15·63	7·25	0·80	74·49	38·78	0·37	0·82
	15	322·14	27·68	−15·22	7·14	0·78	74·81	38·67	0·40	0·85

1894 April 7·3. Autumn equinox of ♂'s northern hemisphere.
1894 August 31·3. Winter solstice „ „ „
1895 February 7·3. Spring equinox „ „ „

Q denotes the position angle, and q the amount of the greatest defect of illumination, E (as in preceding ephemerides) the phase-angle or the areocentric angle between Earth and Sun.

The last column gives the brightness of *Mars* expressed in star magnitudes, the brightness at mean opposition being assumed to be $-1^{m}\cdot787$, according to Prof. G. Müller's determination (in vol. viii. of the *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*), and the diminution of brightness due to the phase being computed on two suppositions—(I) that it depends simply on the proportion of the unilluminated portion to the whole of the disc, so that the alteration of magnitude amounts to $+5$ log sec $\frac{1}{2}$ E; or (II) that the alteration is repre-

sented by Müller's empirical formula $+0^{\circ}.01426\,\alpha$, in which the phase angle α (here E) is expressed in degrees.

The data of the ephemeris are to be interpolated directly for the times for which they are required, since the equation of light has already been taken into account. The differences between successive values of the areographical longitudes of the centre vary from $700^{\circ}.33$ to $702^{\circ}.43$.

The adopted zero meridian will pass the centre of the disc at the following Greenwich mean times:—

1894.	h	m	1894.	h	m	1894.	h	m
May 31	3	35·2	July 2	0	25·1	Aug. 2	20	58·4
June 1	4	15·6	3	1	5·3	3	21	37·8
2	4	56·1	4	1	45·4	4	22	17·1
3	5	36·5	5	2	25·4	5	22	56·4
4	6	16·9	6	3	5·5	6	23	25·6
5	6	57·4	7	3	45·6	8	0	14·8
6	7	37·8	8	4	25·6	9	0	54·0
7	8	18·2	9	5	5·6	10	1	33·2
8	8	58·6	10	5	45·6	11	2	12·3
9	9	39·0	11	6	25·5	12	2	51·3
10	10	19·4	12	7	5·5	13	3	30·3
11	10	59·8	13	7	45·4	14	4	9·3
12	11	40·2	14	8	25·3	15	4	48·3
13	12	20·5	15	9	5·1	16	5	27·2
14	13	0·9	16	9	45·0	17	6	6·1
15	13	41·2	17	10	24·8	18	6	44·9
16	14	21·6	18	11	4·6	19	7	13·7
17	15	1·9	19	11	44·4	20	8	2·5
18	15	42·2	20	12	24·1	21	8	41·2
19	16	22·5	21	13	3·9	22	9	19·8
20	17	2·9	22	13	43·6	23	9	58·4
21	17	43·1	23	14	23·3	24	10	37·0
22	18	23·4	24	15	2·9	25	11	15·5
23	19	3·7	25	15	42·5	26	11	54·0
24	19	43·9	26	16	22·1	27	12	32·4
25	20	24·1	27	17	1·7	28	13	10·8
26	21	4·3	28	17	41·2	29	13	49·1
27	21	44·5	29	18	20·7	30	14	27·4
28	22	24·7	30	19	0·2	31	15	5·6
29	23	4·9	31	19	39·7	Sept. 1	15	43·8
30	23	45·0	Aug. 1	20	19·1	2	16	21·9

1894.	h	m
Sept. 3	16	59·9
4	17	37·9
5	18	15·9
6	18	53·8
7	19	31·6
8	20	9·4
9	20	47·1
10	21	24·8
11	22	2·4
12	22	39·9
13	23	17·4
14	23	54·8
16	0	32·2
17	1	9·5
18	1	46·8
19	2	24·0
20	3	1·1
21	3	38·2
22	4	15·2
23	4	52·1
24	5	29·0
25	6	5·8
26	6	42·6
27	7	19·3
28	7	55·9
29	8	32·5
30	9	9·1
Oct. 1	9	45·6
2	10	22·0
3	10	58·4
4	11	34·8
5	12	11·1
6	12	47·3
7	13	23·8
8	13	59·7
9	14	35·9
10	15	12·0
11	15	48·1
12	16	24·2

1894.	h	m
Oct. 13	17	0·3
14	17	36·4
15	18	12·4
16	18	48·4
17	19	24·5
18	20	0·5
19	20	36·5
20	21	12·5
21	21	48·6
22	22	24·6
23	23	0·7
24	23	36·8
26	0	12·9
27	0	49·1
28	1	25·3
29	2	1·5
30	2	37·7
31	3	14·0
Nov. 1	3	50·3
2	4	26·7
3	5	3·1
4	5	39·6
5	6	16·1
6	6	52·7
7	7	29·3
8	8	6·0
9	8	42·8
10	9	19·6
11	9	46·5
12	10	33·4
13	11	10·4
14	11	47·4
15	12	24·5
16	13	1·7
17	13	38·9
18	14	16·2
19	14	53·6
20	15	31·0
21	16	8·5

1894.	h	m
Nov. 22	16	46·0
23	17	23·6
24	18	1·3
25	18	39·0
26	19	16·8
27	19	54·7
28	20	32·6
29	21	10·5
30	21	48·5
Dec. 1	22	26·6
2	23	4·7
3	23	42·9
5	0	21·1
6	0	59·3
7	1	37·6
8	2	16·0
9	2	54·4
10	3	32·9
11	4	11·4
12	4	49·9
13	5	28·5
14	6	7·1
15	6	45·8
16	7	24·5
17	8	3·2
18	8	42·0
19	9	20·8
20	9	59·7
21	10	38·6
22	11	17·5
23	11	56·4
24	12	35·4
25	13	14·4
26	13	53·4
27	14	32·4
28	15	11·5
29	15	50·6
30	16	29·7
31	17	8·9

1895.	h	m	1895.	h	m	1895.	h	m
Jan. 1	17	48·1	Jan. 17	3	38·2	Feb. 1	13	31·1
2	18	27·3	18	4	17·6	2	14	10·7
3	19	6·5	19	4	57·1	3	14	50·3
4	19	45·8	20	5	36·6	4	15	29·9
5	20	25·1	21	6	16·1	5	16	9·5
6	21	4·4	22	6	55·6	6	16	49·1
7	21	43·7	23	7	35·1	7	17	28·8
8	22	23·0	24	8	14·6	8	18	8·4
9	23	2·3	25	8	54·1	9	18	48·0
10	23	41·7	26	9	33·7	10	19	27·7
12	0	21·1	27	10	13·2	11	20	7·3
13	1	0·5	28	10	52·8	12	20	46·9
14	1	39·9	29	11	32·4	13	21	26·6
15	2	19·3	30	12	11·9	14	22	6·2
16	2	58·7	31	12	51·5			

The present ephemeris is founded upon the same elements as those for the preceding oppositions, as this year's observations will probably yield such effective contributions towards a closer determination of the position of the planet's axis, and of the leading points of areography, that it would be premature to make any alterations till the results of the observations are known. In this respect it is specially desirable to get good places of Schiaparelli's *Sinus Titanum*, since those obtained in 1879 are not sufficiently accordant, and also good places of the *Fastigium Aryn* and of the region near. The *Sinus Titanum* will pass the central meridian near the centre of the disc, about 11^h 6 after the passage of the zero meridian.

As Schröter's sketches Nos. 25 and 26* were made just a hundred years ago, in 1794, the present occasion seems not unsuitable for pointing out, in fairness to them, that they represent, however imperfectly, the region of the Kaiser Sea or Syrtis, or Mer de Sablier. The reason why there has been any difficulty in their interpretation is to be found in a simple slip in writing or mistake in reading. The two sketches were made in the month of May, not März, or March, 1794. This is indicated already by the aspect of the unilluminated portions of the discs, which are shown to be on the following (not the preceding) side, and somewhat less than in the next sketch, dated June 1. Moreover, Schröter expressly states that the time of No. 25 was $30\frac{1}{2}$ days after the opposition, which occurred on the morning of April 24, so that *after* gives the evening of May 24, while *before* would give the printed date. But at the given hour of March 24 *Mars* was not yet above the horizon.

* J. H. Schröter, *Areographische Beiträge*, herausgegeben von Van de Sande Bakhuyzen, 1881, and also C. Flammarion, *La Planète Mars*, 1892, p. 72.

Errata.

In Mr. Innes' paper, *Monthly Notices*, vol. liv.

Page 292, line 5 from bottom,

for 9·553121 *read* 9·5531214.

Page 295, bottom line,

for 9·4553008 *read* 9·4543008.

1895.		
Jan.	1	
	2	
	3	
	4	

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. MAY 11, 1894. No. 7

Captain W. de W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

Rev. Samuel Robert Browne, M.A., LL.D., Bristol Grammar School, and Camelot, St. John's Road, Clifton, Bristol;
Rev. F. J. Eld, M.A., Whiteladies, Worcester;
Henry Owen, F.R.G.S., F.R.Met.Soc., Royal Thames Yacht Club, 7 Albemarle Street, W.;
George C. Pulsford, Royal Hospital School, Greenwich, S.E.;
W. Rickmer Rickmers, Schwarzspanierstrasse 18, Vienna; and
William Stewart Stewart, Levern House, Barrhead, Scotland,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Major Archibald Drummond, Scots Guards, Guards' Club, Pall Mall, S.W. (proposed by the Earl of Crawford);
S. Maitland Baird Gemmill, care of W. L. Wilson, 254 St. George's Road, Glasgow (proposed by Lord Kelvin); and
Samuel A. Saunder, M.A., Mathematical Master at Wellington College, Berks (proposed by H. F. Newall).

The following were proposed by the Council as Associates of the Society :—

Albert A. Michelson, University of Chicago, U.S.A. ;
H. Poincaré, Paris.

Seventy-six presents were announced as having been received since the last meeting, including amongst others a series of lantern slides from photographs taken at Sydney Observatory, presented by H. C. Russell.

Report of the Joint Solar Eclipse Committee of the Royal Society, the Royal Astronomical Society, and the Solar Physics Committee, for the observation of the Solar Eclipse of 1893 *April* 16.

(*Communicated by Dr. A. A. Common, Secretary of the Committee.*)

The Committee has done the work which it was constituted to do, and now submits the following Report to the above-mentioned Societies :—

This Committee was formed early in 1892 by the addition to the already constituted Committee of the Royal Astronomical Society of eighteen members nominated by the Royal Society and of eight members nominated by the Solar Physics Committee. Some of the members thus nominated were already members of the old Committee. The original number of the Joint Committee was thirty-two. One new member has been added.

The Committee has to regret the death of two of its members—the Rev. Professor Pritchard, F.R.S., and Mr. H. T. Blandford, F.R.S.

The first meeting of the Committee was held on 1892 May 27, followed by three others on June 17, November 23, and 1893 January 25. At these meetings the work to be undertaken was determined upon and the observers selected; and although a careful estimation of the cost of sending two expeditions (one to Africa and one to Brazil) showed that the amount of money applied for from the Government Grant Fund of the Royal Society was not quite enough, the great advantage that would be gained by two such expeditions so widely separated quite warranted the Committee in sending them.

It was therefore decided to send one expedition to West Africa, under the charge of Dr. Thorpe, and another to Pará Curu, in Northern Brazil, under the charge of Mr. A. Taylor, and that the work done at each station should be of the same

kind. At the African station, however, Dr. Thorpe would undertake, in addition, to make similar observations bearing on the photometric intensity of the coronal light to those he had already made in Grenada in 1886.

The work to be done at each station was :—

1. Photographs of the corona by means of a lens lent by Captain Abney, in continuation of a long series of photographs already obtained at previous eclipses.
2. Photographs of the corona on a larger scale and with a shorter exposure (relatively).
3. Photographs of the surroundings of the Sun, taken by means of a lens with prisms in front.
4. Photographs of the spectrum of the corona with slit spectroscopes.

The work mentioned in the first and second paragraphs above necessitated the construction of a double camera, as it was important to get the two photographs on the different scales taken together. The size of the larger image was about three times that of the smaller. The exposures were arranged so that the longer exposure of the large picture would be comparable with the shorter exposure of the smaller.

Two double tubes were made with dark slides carrying two plates each, and mounted on telescopes lent by the Admiralty.

The work referred to in the third paragraph was undertaken at the suggestion of Mr. Lockyer, who undertook the whole arrangement as to supply of instruments and times of exposure.

The slit spectroscopes in use in Africa were mounted on an equatorial stand lent by the Astronomer Royal. In Brazil the heliostat used for the other spectroscopic work gave the light to fixed spectroscopes.

The Committee were not only very fortunate in getting a sufficient number of observers for the work, but, as events proved, perhaps the very best men that could have been chosen for each class of work.

Dr. Thorpe took charge of the African expedition, and of the work already mentioned to be done by him, and was assisted by Mr. Gray, and also by Mr. Forbes, who went out as a volunteer and at his own cost. The double coronagraph was in charge of Sergeant Kearney, R.E. ; Captain E. H. Hills, R.E., who was also a volunteer and went out at his own expense, had charge of the slit spectroscopes ; and Mr. A. Fowler, of the Royal College of Science, had charge of the prismatic camera. Mr. A. Taylor took charge of the Brazilian expedition, and was assisted by Mr. Shackleton, who had charge of the prismatic camera there, Mr. Taylor using the double coronagraph and the slit spectroscopes. The selected place of observation on the line of totality was in each case on foreign territory. At the request of the Committee the Royal Society made the necessary application,

through the Foreign Office, for permission to land and put up instruments, and for other facilities, to the French and Brazilian Governments; this in each case was most kindly accorded.

In Africa the point selected as giving the best chance of fine weather was some distance from the coast up the Salum River, and only to be reached by vessel. The Admiralty kindly placed at the disposal of the expedition a gunboat for this service, which met the expedition at Bathurst, took it to the selected spot near Fundium, attended it there, and brought it back to Bathurst when the eclipse was over.

As the return mail-boat from Bathurst did not leave for some time after the return of the expedition there, the Admiralty kindly placed another vessel at the service of the expedition to bring it on to Teneriffe. The eclipse was observed under very favourable circumstances (only a slight haze prevailing), and the results obtained were most successful in every way.

Except for an over-exposure of one of the slit spectroscopes, not in any way due to Mr. Taylor, who had to rely on volunteer assistance in this, the results obtained by the Brazilian expedition were equally successful.

The observers here had to travel much further; after the voyage to Pernambuco, a coasting voyage to Ceara, and another to Parazinho, with trans-shipment of baggage under considerable difficulties, had to be done. On arrival at Parazinho, the luggage had to be got on shore by native rafts of a very primitive character, and then taken two kilometres up country, to Pará Curu, on bullock waggons. This was accomplished by April 3. The work of getting houses built for the instruments, and the instruments set up and adjusted, was at once begun; and although continual cloud, combined with heavy rain, very much interfered with the work, the whole of the arrangements were completed before the eclipse, and three days of rehearsals were obtained.

The morning of the eclipse was cloudy, and there seemed very little chance of getting any results; but everything was arranged to carry on the operations, and the clouds were anxiously watched for a break. Fortunately this break in the clouds came, and the eclipse was observed under excellent conditions.

Mr. Taylor and Mr. Shackleton must have worked in a most praiseworthy way to have got all ready under such very discouraging circumstances, without any such help as could have been given by a gunboat's crew, which almost seems a necessity when instruments have to be landed on practically a barren shore.

Since the return of the expeditions, the Committee has met, on 1893 June 5, and on January 12 and May 2 of this year, to consider the publication of the reports of the various observers, and to arrange for a settlement of the various accounts for expenses incurred.

With regard to publication, the following arrangements have been made:—Dr. Thorpe is preparing and will send to the Royal Society his report on the work he undertook in Africa. Mr.

Lockyer has already sent in to the Royal Society a preliminary report on the results obtained with the prismatic cameras in Africa and Brazil. Captain E. H. Hills has prepared, and the Committee has communicated to the Royal Society, a report on the slit spectroscope photographs obtained in Africa and Brazil.

A report on the corona photographs, taken with the double coronagraph by Mr. Taylor in Brazil and Sergeant Kearney in Africa, with a selection of the photographs for reproduction, and a Paper giving the results of a comparison of the various photographs made by Mr. W. H. Wesley, with a view of detecting any change in the form of the corona, is almost ready, and will be presented to the Royal Astronomical Society for publication, in continuation of similar work already published by this Society.

With regard to the cost of the expeditions, this has considerably exceeded the estimates first made as to the probable cost, particularly in the case of the Brazilian expedition, where, from the nature of the case, the expense has been very heavy. The cost of this expedition was 376*l.* 6*s.* 1*d.*; of the African expedition, 279*l.* 0*s.* 8*d.*; of instruments, plates, and sundries, 157*l.* 5*s.* 7*d.*; making a total of 812*l.* 12*s.* 4*d.*

The original grant of the Royal Society from the Government Grant Fund was 600*l.*; this was supplemented by a further grant of 100*l.*, and the Royal Astronomical Society, on the application of the Committee, gave 112*l.* 12*s.* 4*d.*, thus enabling the Committee to pay all expenses incurred.

The accounts for the money spent have been examined by the auditor appointed by the Committee (General Tennant), and certified correct, and will be sent to the Government Grant Committee in due course.

The recently formed Committee of the Royal Society and the Royal Astronomical Society has kindly undertaken to take charge of the photographs and papers in connection with the 1893 eclipse, and to deal with any question that may arise, which would otherwise come before the Joint Committee.

The members of the Committee, in concluding this Report, wish to put on record their thanks to the Admiralty for the services of H.M.S. *Alecto* and H.M.S. *Blonde* in connection with the African expedition; to the French and Brazilian Governments for the facilities afforded to both expeditions; to the Royal Society, the Royal Astronomical Society, and the Solar Physics Committee, and to the Astronomer Royal, Mr. Lockyer, and Captain Abney for the loans of instruments; to the observers who went to Africa and Brazil, whose names are already mentioned in this Report; and for help in other ways to the following gentlemen amongst others :—R. B. Llewellyn, C.M.G., Administrator at Bathurst; M. Victor Allys, Administrator at Fundium; the Directors of the British and African Steamship Company; the Directors of the Spanish National Submarine Telegraph Company; H.E. the Governor of Ceara; Mr. A. T. G. Williams, H.M.'s Acting Consul at Pernambuco; Mr. G. Holdernesse,

Vice-Consul at Fortaliza; Mr. Reidy, Manager of the Western Brazilian Submarine Telegraph Company; Mr. P. O'Meara, late Chief Engineer of the Port Works, Ceara; M. N. Olsen, Fortaliza, Ceara; Colonel Jas. Brigido, Ceara; and the Directors of the Royal Mail Steamship Company.

1894 *May* 2.

Two Questions on Mr. Stone's Proposed Correction to the Measure of Time. By Professor Simon Newcomb.

From Mr. Stone's note on p. 288 of the *Monthly Notices* for March it would seem that he has not carefully read the short Paper to which his note alludes. This Paper contains no attempt to disprove Mr. Stone's views, nor were any quantities in his theory neglected; on the contrary, the Paper was principally an attempt to apply his theory, as he states it, to the special case of the transit of the Moon observed at Oxford on 1892 January 6, on the supposition that the use of Le Verrier's tables, and the consequent introduction of the new measure of time, commenced in 1892. An inconsistency was found, and Mr. Stone was asked to explain it. He says nothing about this observation, and gives no explanation of the inconsistency. I therefore beg that Mr. Stone will answer these two questions:—

(1) What would have been the tabular error of Hansen's tables of the Moon given by the transit observed at Oxford on 1892 January 6, and printed on p. 4 of the *Monthly Notices* for the present session, if Carlini's tables of the Sun had been continued in use in the *Nautical Almanac* until the present time?

(2) What would have been the tabular error given by the same observation had Carlini's tables been continued until the end of 1891 and Le Verrier's introduced for the first time in 1892?

Either Mr. Stone can answer these very simple questions or he cannot. If he can answer them, I respectfully submit that it is only just to himself that he should do so, giving the numerical computation in each of the two cases fully enough to be understood, comparing it with the actual computation on p. 4, and showing how the result follows from his theory. If he cannot answer them, nothing more need be said.

Reply to Professor Newcomb's Two Questions. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

Before answering Professor Newcomb's two questions, I feel it necessary to call attention to his statement that in the *Monthly Notices* for March he applied my theory to the special case of the transit of the Moon at Oxford on 1892 January 6, and "without neglecting any quantities in my theory" was led to an inconsistency. Now, this statement is certainly inaccurate. It is simply because Professor Newcomb has neglected certain quantities which, if my views of the physical bases of our time-measures are sound, cannot be neglected without error, that the inconsistency arises; and in my reply I called Professor Newcomb's attention to this point as the real one at issue, but apparently without success.

I now come to Professor Newcomb's questions.

1. "What would have been the tabular error of Hansen's tables of the Moon given by the transit at Oxford on 1892 January 6 if Carlini's tables of the Sun had been continued in use in the *Nautical Almanac* until the present time?"

I understand by this question that the data given in the *Nautical Almanac* are supposed to have been continuously *used for the computation of our "sidereal times at mean noon," and in the actual determinations of our local sidereal times*, and not merely printed without being used. In this case the answer is that the R.A. from Hansen's tables *minus* observed R.A. on 1892 January 6 would have been $= -0^s{\cdot}10$, the result which is given in the *Monthly Notices* for November, and is quoted by Professor Newcomb under the form "Hansen *minus* observed, corrected." I have published the answers to *this and similar questions for all the observations of the Moon made at Oxford since* 1880.

2. The answer to the second question is that the effects produced on $-0^s{\cdot}10$, in the supposed case, would be very small; for they would merely be those due to the difference between the "local sidereal time," which would, if no change had been made, have been accepted by astronomers as 1892 January 1, subject, of course, to any errors of that assumption, and that which would have been accepted as the epoch 1892 January 1, the instant of departure for the new system of time-measures, together with the difference between the sidereal equivalents for the two different intervals of absolute time used as "unit days" before and after the change, multiplied by the number of "unit days" which had elapsed since the change was made, which in the cases supposed would be equal

$$5 \times \left[86400^s \left(\frac{N + \delta N}{N_0} + \frac{N + \delta N}{2\pi} \right) - 86400^s \left(\frac{N}{N_0} + \frac{N}{2\pi} \right) \right]$$

$$= 5 \times 86400 \frac{dN}{N_0} \left(1 + \frac{N_0}{2\pi} \right)$$

where dN is the difference between the values of the Sun's mean motion in longitude used in the construction of Le Verrier's and Carlini's solar tables, N_0 the Sun's mean motion in the "physical" as distinguished from the "unit day." In the computation of the small corrections it is sufficient to replace N_0 by N or $N + \dot{c}N$. The method is, I hope, here explained in sufficient detail for anyone to follow; it is applicable to all such cases, and it is the one which I have used in allowing for the changes in the scales of time-measurement.

Having given distinct answers to Professor Newcomb's two questions, I may perhaps be allowed to explain that the corrections which I have applied in passing from a system of time-measures based on the use of one set of solar tables to those based on the use of a different set of solar tables, are strictly deduced from, and are the necessary mathematical consequences of, the physical bases upon which our measures of time rest. It is the use of two independent systems of time-measures, one based on the geocentric motion of the Sun, the other on the motion of the meridians in right ascension, and the adoption of different, and therefore, at times, erroneous, values of the ratio of a "mean tropical year" to a "mean sidereal day," to transfer "mean solar times" into "sidereal times," and *vice versâ*, which has led to error.

The subject is fully discussed in my paper in the *Monthly Notices*, 1893 December, and need not be repeated here.

But there is one point to which it is perhaps desirable that attention should be called, from the stress which Professor Newcomb lays upon his "table-of-logarithms" argument.

If quantities θ^s are computed from a definite function $f(t)$ of any variable t, in which the "angles" have been expressed in "time" at the rate of 86,400 seconds to an angle 2π, the quantities θ^s thus obtained for assigned values of the variable t will be identical whenever computed, and if we call the unit in terms of which t is expressed a "mean solar day," the quantities θ^s computed from the equation

$$\theta^s = f(t)$$

will be identically the same for the same "mean solar time"; but the physical meaning of the variable t is not fixed by any such nomenclature. And although the numerical results will be the same whether the computations were made thirty years ago, are made now, or shall be made thirty years hence, it is *not* true that the *interval of time* which is called a "mean solar day" in practical astronomical work is independent of the conditions between the variable t and the facts of observation by which it is rendered determinate; it is not true that it cannot be changed by alterations of these conditions; it is not true that different errors in our time-determinations will not result from the introduction of different inconsistent conditions between the variable t and the facts of observation from which

our times are found; and it is not true that the "mean solar day" as thus fixed will be independent of *any use which we may make of the computed quantities* θ^s *during definite periods* in the actual determination of our "times" from observation. But these assumptions appear to me essential to give any force whatever to such arguments as those brought forward by Professor Newcomb against my views. But instead of these assumptions being true, the length of the *interval of time* which is taken as the "unit day," and called a "mean solar day," in such cases will be absolutely fixed by the conditions introduced between the facts of observation and the variable t by the particular results of observation with which we identify the computed quantities θ^s to render t determinate; and the times will be deducible from the equations of condition thus established, either exactly or only approximatively, according as the secular and periodic variations from the mean motion are perfectly or imperfectly allowed for in our theoretical investigations.

In practice we take the quantities θ^s computed from a definite formula,

$$\theta^s = f(t),$$

or extracted from a selected set of solar tables, and use them as the "local sidereal times at the meridian transits of the Sun" for the corresponding "mean solar times"; and we find our "local sidereal times" from observation, and therefore the "right ascensions of the Sun from observation," subject to the conditional relation between the local sidereal times and the variable t, or the mean solar times, thus established.

The use of a set of solar tables in this way for the determination of the local sidereal times *absolutely* fixes *the particular interval of time which is adopted as the "mean solar day" so long as the same set of solar tables is continuously used.* I have called the "mean solar day" thus fixed a "unit day" to distinguish it from the "physical" or "true" "mean solar day," an interval of time which we cannot change, although we can adopt different units in terms of which to express its length and that of any other intervals of time with which we may be concerned. The "unit day" thus fixed by the adoption and use of a set of solar tables in the construction of which an angle N has been used for the Sun's mean motion in longitude in a "unit day" will contain

$$86400\left(\frac{N}{N_0} + \frac{N}{2\pi}\right) \text{. sidereal seconds;}$$

where N_0 denotes the Sun's mean motion in the "physical mean solar day."

The errors made by replacing N_0 by the value N, adopted by Carlini, and the value $N + \delta N$, adopted by Le Verrier, cannot both be insensible. And the differences between the terms which

astronomers have neglected, before and after 1864, are such that they account for the *per saltum* change in the errors of Hansen's lunar tables as thus erroneously compared with observation.

If the "mean solar times" were always directly found, as they might be, subject only to errors of observation and of computation of the "equation of time," from the equation

$$\text{Local sidereal times at meridian transits of Sun} = f(t),$$

the change of the scale of time-measurement with the adoption of different solar tables in 1864 would have been directly apparent. To assume otherwise would be to assume that changes in the solar tables adopted for use lead to different "local sidereal times" for the "meridian transits of the Sun." But the change of time-scale is no less real because it has been generally overlooked, and if, whilst finding our local sidereal times, subject to the condition

$$\text{Local sidereal times at meridian transits of Sun} = f(t),$$

we introduce conditional relations between the variable t and the local sidereal times which are inconsistent with this condition, we cannot escape the consequences of these errors on our time-determinations; and it is these consequences which I have traced.

If Professor Newcomb is prepared to deny that we do *use a set of solar tables to render our local sidereal times observationally determinable*, it is desirable that he should state this. We should in this case be at issue about a matter of fact. But if such is not the case, he must *prove* and not assume that my mathematical deductions are erroneous; or my results should be accepted.

On some possible Improvements in Meridian and Extra-Meridian Observing. By Professor H. H. Turner, M.A., B.Sc.

1. The very interesting and important Paper by Dr. Gill, printed in the last number of the *Monthly Notices*, will at least have set many astronomers a-thinking.

The final answers to the three questions with which he concludes his paper cannot yet be given; but he is undeniably in the right in calling for a reconsideration of our astronomical methods—for a report by astronomers upon the organisation of exact astronomy. It is yet to be determined whether an International Congress or Congresses can be assembled successfully to this end. But if this project falls through, there is no reason why an effort should not be made at the present time to set down definitely in print floating ideas on the subjects to which Dr. Gill has referred in his paper; and if happily the

congresses meet, it will certainly facilitate their labours to have before them in type any definite proposals which may crystallize from discussion.

For this reason I venture to set down one or two small matters which have recently occupied my thoughts at intervals, in the hope that, if valueless in themselves, they may perhaps provoke criticism, comment, or digression which may serve a useful purpose. The theoretical advantages of any new method are apt to shine more brightly before practical trial than after, and are well known to be rapidly dimmed in lustre by the inevitable practical defects which experience reveals. I am therefore conscious that an apology is needed for thus calling attention to methods which are as yet untried; but I hope that Dr. Gill's Paper provides me with something like an excuse.

2. There are probably few who have worked with the transit-circle who have not also speculated on the possibility of avoiding some of its sources of error. Suppose we replace the telescope by a plane mirror, normal to the line of collimation, which is mounted between two carefully made pivots, and can be rotated about a horizontal axis in a manner precisely similar to a transit. And let us observe the image of a star by reflection from this mirror through a telescope *fixed* in the meridian at an arbitrary zenith distance, and pointing to the centre of the mirror; setting the mirror to the position appropriate to the N.P.D. of the star observed. It would seem that by an arrangement of this kind we should secure the following advantages over the simple transit-circle:—

(*a*) The observer might be under cover in a warm room and in comparative comfort; which is a condition of great importance in observing.

(*b*) His position would be the same for all stars; which would eliminate a considerable element of variability in his personal equation.

(*c*) In zenith distance observations many of the refraction difficulties would be avoided. The rays of light from a star to the mirror would not encounter any of the heated strata of air which necessarily occur in a transit-circle room, for the mirror could be in the open. In passing from the mirror to the observer such strata would be encountered, but they would be the same for all stars.

(*d*) The effect of flexure in a reflecting surface is much greater than (say) in an object-glass. But by making the mirror thick enough relatively to its aperture flexure may be reduced to insensible dimensions, and the instrument would then compare favourably with the ordinary transit-circle with its long tube, which is very liable to flexure.

(*e*) To develop advantage (*a*) to its full extent, the observer must be able to make all the necessary observations without moving from his seat at the telescope, including circle readings, and readings of the barometer and thermometers. There would

not seem to be any serious practical difficulty in arranging this, much in the same way as the numerous readings are made from the eye-end of a modern equatorial.

(*f*) The angle of incidence of the light of a star on the mirror is only small for a limited range in zenith distance so long as we use the same fixed telescope. But several fixed telescopes at different zenith distances might be used, and the results would very usefully check one another. Or the same telescope might be fixed in different positions from time to time, without disturbing the adjustments of the movable parts of the instrument—viz. the revolving mirror.

3. With the slight addition of a fixed telescope *not* in the meridian the *same mirror* can be converted into an extra-meridional instrument. Such a telescope will command, as the mirror revolves, a small circle of the sky whose pole is the east or west point, and whose angular radius is the inclination of the telescope to the west or east direction. The errors of adjustment of the revolving mirror may be determined by the meridian observations, the fixed telescope only introducing two additional constants—say its altitude and azimuth. This combination of telescope and mirror corresponds to a transit-circle whose telescope is inclined to the horizontal axis, and describes a cone instead of the meridian. The hour angle at which a body crosses the small circle commanded by such an instrument is independent of the latitude, and depends only on the declination of the object and the inclination of the telescope to the horizontal axis. The latitude of course affects the circle reading at transit; but there is an obvious advantage in not having the latitude enter into both co-ordinates, as in the case of the altazimuth.

4. Once the revolving mirror is set up, it may in fact be used to reflect into a regular battery of fixed telescopes. The project sounds an extravagant one, but these telescopes need not be large—say, 4 inches aperture—and much may be done with a single telescope placed in various positions if its co-ordinates be carefully determined on each occasion of shifting. A pair of telescopes, one of which was left untouched during the removal of the other, would give a virtually continuous series of observations.

5. Circles are now so admirably graduated that perhaps the circle is the part of a meridian instrument least in need of improvement. But the labour of determining division errors, and the risk of systematic error even after a careful determination, are responsible for the following crude suggestion. Returning to the mirror of paragraph 2, suppose a hoop whose centre is on the horizontal axis to be rotated by clock-work, and a mark on its inner surface to be reflected by the mirror into the field of view of a small telescope, fixed near the transit telescope; the rotation of the hoop would cause the image of the mark gradually to cross the field of view and disappear. But a second mark might be added which would appear as the first disappeared; and a

third again, and so on ; so that, in whatever position the mirror was placed, some mark on the hoop (which could be otherwise identified) would be crossing the field of view of the small telescope. Then the position of the mirror would be determined by the time of transit of the particular mark. The intervals of marks round the hoop would be determined by transits at leisure. Some accidental errors would doubtless be introduced by this method ; but the great safeguard against systematic error would be that the zero point would be different on each night, depending simply on the moment of starting the clock-work which rotates the hoop.

6. Concerning the clock, which would become of vital importance in both co-ordinates, if any idea such as that in paragraph 5 were carried into practice, the time would seem to have arrived when observatories of the first class should have not one standard clock, but a number, all kept at a nearly constant temperature, and isolated as far as possible from each other. Here, again, it is far easier to make a suggestion than find the necessary funds to carry it out. The idea of Professor Mendenhall and others, that a free pendulum should be used as an ultimate standard of reference as far as possible, is also well worthy of consideration.

The Effect of Personality in Observations of the Sun's Right Ascension on the Determination of the Position of the Ecliptic. By F. W. Dyson and W. G. Thackeray.

(*Communicated by the Astronomer Royal.*)

In the introduction to the Five-Year Greenwich Catalogue of Fundamental Stars, shortly to be published, it is shown that the observations of the Sun for the years 1887–1891 indicate a correction of $+^{s}\cdot043$ to the adopted right ascensions of the clock-stars used in those years. It was considered advisable not to apply so large a correction to the right ascensions, and the Five-Year Catalogue is therefore referred to the epoch of the standard right ascensions of the Ten-Year Catalogue of 1880. Since then it appears, from the discussion of the position of the ecliptic for 1892 and 1893, that this large correction is more than confirmed, and if no cause can be assigned for it, then, following the precedent of previous years, a large correction to the right ascensions of all stars will be required in the next Greenwich Catalogue.

As the instrument, tables, and method of reduction are the same, and the only element of change in connection with the observations is the observing staff, it seems reasonable to infer a probable cause in the change in the *personnel* of the observers. It is well known that observers have large personal equations in measuring both the horizontal and vertical diameters of the Sun with the

transit-circle. But it does not seem to be equally well recognised that distinct and well-marked personalities appear in the right ascension of the Sun's centre, deduced from observations of the two limbs. Nor are the serious discordances which may arise from this cause in the values of the correction to the equinox sufficiently appreciated.

The observations of R.A. are reduced with each observer's own clock-error; or in those few cases where the observer himself has not been able to obtain a clock-error, the clock-error with which the observation is reduced is always first corrected for difference in the stellar personal equations, so that the error we are considering arises from the difference of personal equation in taking observations of the Sun and stars.

The R.A.'s and N.P.D.'s deduced from the observation are compared with the tabular places given in the *Nautical Almanac*, which since 1864 have been computed from Le Verrier's tables. The differences are given in the annual volumes of Greenwich *Observations* as apparent tabular error. These quantities are grouped in months, and the error of ecliptic N.P.D. obtained by means of Sir G. B. Airy's P.Q.R.S. tables. On the assumption that these errors can be represented by an equation of the form

$$x \cos l + y \sin l + z,$$

when l is the Sun's longitude, twelve equations are formed, which, solved by the method of least squares, give the apparent tabular errors in the position of the equinox, obliquity of the ecliptic, and adopted colatitude.

It will be convenient to point out the exact effect of errors in the right ascension and declination on x, y, and z. The error in ecliptic N.P.D. = R × error in R.A. + S × error in N.P.D. S only varies between + 1 and + 0·9; but R has a considerable range, being equal to 15 sin ϵ cos l, where ϵ is the obliquity of the ecliptic.

Denoting by

e the observed error in R.A.

f " " N.P.D.

and

n the number of observations,

there are n equations determining x, y, z, of the form

$$x \cos l + y \sin l + z = 15\, e \sin \epsilon \cos l + Sf.$$

The normal equations are

$$x\Sigma \cos^2 l + y\Sigma \sin l \cos l + z\Sigma \cos l = 15 \sin \epsilon \Sigma e \cos^2 l + \Sigma Sf \cos l,$$

$$x\Sigma \sin l \cos l + y\Sigma \sin^2 l + z\Sigma \sin l = 15 \sin \epsilon \Sigma e \sin l \cos l + \Sigma Sf \sin l,$$

$$x\Sigma \cos l + y\Sigma \sin l + z \,.\, n = 15 \sin \epsilon \Sigma e \cos l + \Sigma Sf.$$

If the n observations are distributed fairly evenly throughout the year

$$\Sigma \sin 2l, \Sigma \cos 2l, \Sigma \sin l, \Sigma \cos l \text{ all} = 0.$$

$$\Sigma \sin^2 l = \Sigma (\tfrac{1}{2} - \tfrac{1}{2} \cos 2l) = \frac{n}{2}$$

$$\Sigma \cos^2 l = \Sigma (\tfrac{1}{2} + \tfrac{1}{2} \cos 2l) = \frac{n}{2}.$$

Therefore the normal equations are

$$\left.\begin{aligned} \frac{n}{2} x &= 15 \sin \epsilon \Sigma e \cos^2 l + \Sigma S f \cos l \\ \frac{n}{2} y &= 15 \sin \epsilon \cdot \Sigma e \sin l \cos l + \Sigma S f \sin l \\ nz &= 15 \sin \epsilon \Sigma e \cos l + \Sigma S f. \end{aligned}\right\}$$

These equations show

1. That a constant systematic error e will produce

(α) in x the error

$$\frac{2}{n} \cdot 15 \sin \epsilon \, e \Sigma \cos^2 l, \text{ } i.e. \text{ } e \, 15 \sin \epsilon,$$

or directly affects the position of the equinox ;

(β) in y the error

$$\frac{2}{n} 15 \sin \epsilon \cdot e \Sigma \sin l \cos l, \text{ } i.e. = 0;$$

(γ) in z the error

$$\frac{1}{n} \cdot 15 \sin \epsilon \, e \Sigma \cos l, \text{ } i.e. = 0.$$

2. An error in f systematically of one sign in the first half of the year and the opposite in the second half of the year has an important effect on x, none on y or z. An error in f systematically of one sign in the summer and the opposite in the winter would have an important effect on y, but none on x and z.

An error in f of the same sign throughout the year has an important effect on z, but none on x and y.

Therefore any personality (e) an observer has in taking the right ascension of the Sun gives an error $15 \sin \epsilon \cdot e$ in the value of x, and therefore an error e in the absolute right ascensions of all the clock-stars. An error of the nature of Chandler's latitude variation, having a period of fourteen months, which is not far removed from an annual period, would have an important effect on x or y according as its maximum and minimum values were near the equinoxes or the solstices. Thus Chandler's variation of the latitude will in some years affect the value of x and in other years the value of y to the extent of $^{s}\cdot 050$.

In the present paper we propose to confine ourselves chiefly to the effect of personality in observing right ascensions of the Sun, as the N.P.D.'s of the Sun before 1878 are not immediately available for this purpose, requiring considerable systematic corrections to make them comparable with the observations made since. The introduction of Le Verrier's tables in 1864 into the *Nautical Almanac* computations of the Sun's place will afford a proper date for the period from which to begin, as far as the Greenwich observations are concerned. As a check on our deductions, and as affording valuable additional data, we have also discussed the Washington observations since 1872 up to 1887, during which period Professor Eastman has continuously observed.

The daily observations of the Sun are exhibited both in the Greenwich and Washington publications in the planetary sections, in the former as tabular errors, in the latter as corrections to the ephemeris. From these sections the various quantities thus given are taken and tabulated under the various observers' initials, and the yearly mean then taken, only those observations being used in which both limbs were observed. In the case of the Greenwich observations, we have grouped under the heading "Miscellaneous" all observers other than the regular observing assistants, as the number of observations of any one was too few, and the period during which he observed too short, for the accurate determination of his personal equation.

TABLE I.

Greenwich Mean Tabular Errors of R.A. of Sun (from mean of both limbs).

	D.		E.		C.		J. C.			Miscellaneous.		Mean.	
	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.		s	No. of Obs.	s	No. of Obs.
1864	+·019	14	−·012	23	+·010	26	−·067	18	...	+·074	23	+·007	104
1865	−·010	14	+·015	22	+·061	23	−·037	16	...	+·039	25	+·020	100
1866	−·022	13	−·060	20	−·007	16	−·064	17	...	+·054	28	−·012	94
1867	−·020	12	−·087	17	+·057	11	−·068	13	...	−·005	20	−·026	73
1868	+·006	8	−·065	19	+·020	24	+·009	15	...	+·063	36	+·016	102
1869	+·033	12	−·012	17	+·033	13	−·032	13	...	+·043	21	+·015	76
	L.												
1870	+·019	13	−·032	18	+·057	20	−·040	21	...	+·053	32	+·012	104
1871	+·030	22	−·009	14	+·032	14	−·084	14	...	+·096	36	+·033	100
1872	+·065	22	−·058	21	+·001	22	−·079	16	...	+·026	36	−·001	117
							A. D.						
1873	+·056	19	−·028	17	+·025	17	+·059	23	...	+·056	26	+·037	102
1874	+·081	19	−·015	11	+·036	18	+·111	17	...	+·035	28	+·053	93
			T.										
1875	+·081	14	·000	13	+·026	13	+·048	14	...	+·075	41	+·055	95
1876	+·095	10	+·004	20	+·035	13	+·044	22	...	+·080	34	+·052	99
1877	+·030	6	+·005	13	+·053	13	+·031	15	...	+·070	28	+·045	75
1878	...		+·052	11	+·024	14	+·018	14	...	+·069	37	+·049	76
1879	...		+·038	9	+·005	12	+·022	12	...	+·090	26	+·051	59
1880	...		+·046	19	+·010	16	+·007	24	...	+·105	39	+·054	98

	T. L.		T.		C.		A. D.			Miscellaneous.		Mean.	
	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.		s	No. of Obs.	s	No. of Obs.
1881	+·071	26	+·028	16	+·011	15	+·030	21	...	+·062	29	+·046	107
					H.								
1882	+·077	18	+·022	19	+·030	20	+·007	13	...	+·074	18	+·044	88
1883	+·085	19	−·014	23	+·025	17	+·033	20	...	+·085	34	+·046	113
1884	+·081	20	+·009	15	+·014	15	+·003	11	...	+·099	38	+·055	99
1885	+·052	20	+·009	16	+·028	25	+·004	16	...	+·072	38	+·041	115
1886	+·081	16	+·021	11	+·015	24	+·042	18	...	+·105	46	+·065	115
1887	+·086	17	+·018	17	+·007	21	+·025	19	...	+·084	51	+·053	125
1888	+·071	13	+·004	13	+·034	14	+·046	17	...	+·051	30	+·043	87
1889	+·087	14	+·023	12	+·031	19	+·065	19	...	+·085	43	+·065	107
1890	+·054	23	+·069	11	−·023	28	+·040	22	...	+·081	45	+·046	129
									A. C.				
									s No. of Obs.				
1891	+·079	15	+·051	12	+·030	21	+·090	9	+·073 16	+·092	43	+·072	116
			B.				T. H.						
1892	+·072	19	+·104	22	−·001	9	+·064	15	+·067 31	+·103	40	+·080	136
1893	+·047	9	+·137	28	+·007	29	+·104	11	+·068 27	+·120	63	+·090	167

The initials D., E., C., J. C., L., A. D., T., T. L., H., A. C., B., and T. H., are those of Messrs. Dunkin, Ellis, Criswick, James Carpenter, Lynn, Downing, Thackeray, Lewis, Hollis, Crommelin, Bryant, and Hudson.

The heading "Miscellaneous" includes all observations other than those of the assistants observing regularly throughout the year.

In the accompanying tables we have adopted exactly the same method as Mr. Dunkin in his Paper on "Personality" in *Monthly Notices*, 35 (2). For Greenwich we have adopted C. (Mr. Criswick) as our standard, and when he ceased to observe in 1882 we have referred back to him through

$$\frac{\text{A. D.} + \text{T.}}{2},$$

and have thus assumed that A. D. and T. have kept the same personality; this assumption is confirmed by the fact that the difference of personal equation for A. D. and T. was $+^s\cdot017$ before and $+^s\cdot018$ after 1881; and after A. D. and T. ceased observing in 1891 through

$$\frac{\text{H.} + \text{T. L.}}{2}.$$

To connect the period after 1881, when C. ceased to observe, with the following years, we have taken A. D. and T. as our deputy standard, and have taken

$$\frac{\text{A. D.} + \text{T.}}{2} - \text{C.} = +0^s\cdot008.$$

Secondly, to connect A. C., B., and T. H. with C., we have referred them to

$$\frac{\text{T. L.} + \text{H.}}{2},$$

and have taken

$$\frac{\text{T. L.} + \text{H.}}{2} - \text{C.} = +0^s\cdot027.$$

For Washington we have adopted as our standard (Professor Eastman) E., as he has observed continuously throughout the period. In both cases we have adopted the same principles. We have considered it best to assume that variations in the annual means of an observer's tabular errors is either accidental or due to causes which would also similarly affect other observers; therefore we do not attempt to fix any arbitrary periods as to when an observer did or did not change his habit of observing, but we take our standard observer, or his *locum tenens*, and find the mean of his observations, and of any other observer we wish to compare with him, for the period during which they were observing conjointly, and the difference between these results gives us the correction to be applied to the other observer to reduce to the standard. We have, however, divided the group headed "Miscellaneous" into two groups, one conterminous with the observing life of C., and the second with that of A. D. and T. There is some change in the two corrections due, probably, to the larger number of young observers in the latter years.

TABLE II.

Corrections to reduce Tabular R.A.'s of Sun to C. as Standard.

Observer.	Period.	Corr. s	Observer.	Period.	Corr. s
D.—C.	1864-69	+0·025	T. L.—C.	1881-93	−0·055
E.—C.	1864-74	+0·060	H.—C.	1882-93	+0·001
J. C.—C.	1864-72	+0·078	A. C.—C.	1891-93	−0·054
L.—C.	1870-77	−0·026	B.—C.	1892-93	−0·117
A. D.—C.	1873-81	−0·016	T. H.—C.	1892-93	−0·075
T.—C.	1875-81	0·000	Misc.—C.	1882-93	−0·065
Misc.—C.	1864-81	−0·036			

The following table contains the results of Table I. corrected by the quantities in Table II. explained as above.

TABLE III.

Tabular Errors of R.A. of Sun (from mean of both limbs) corrected to C.

	D.		E.		C.		J. C.			Miscellaneous.		Mean of Assistants.	Mean of all.
	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.		s	No. of Obs.	s	s
1864	+·044	14	+·048	23	+·010	26	+·011	18	...	+0·38	23	+·028	+·030
1865	+·015	14	+·075	22	+·061	23	+·041	16	...	+·003	25	+·052	+·040
1866	+·003	13	·000	20	−·007	16	+·014	17	...	+·018	28	+·003	+·008
1867	+·005	12	−·027	17	+·057	11	+·010	13	...	−·041	20	+·007	−·006
1868	+·031	8	−·005	19	+·020	24	+·087	15	...	+·027	36	+·028	+·028
1869	+·058	12	+·048	17	+·033	13	+·046	13	...	+·007	21	+·047	+·036
	L.												
1870	−·007	13	+·028	18	+·037	20	+·048	21	...	+·017	32	+·030	+·026
1871	+·004	22	+·051	14	+·032	14	−·006	14	...	+·060	36	+·020	+·034
1872	+·039	22	+·002	21	+·001	22	−·001	16	...	−·010	36	+·011	+·005
							A. D.						
1873	+·030	19	+·032	17	+·025	17	+·043	23	...	+·020	26	+·033	+·030
1874	+·055	19	+·045	11	+·036	18	+·095	17	...	−·001	28	+·058	+·040
			T.										
1875	+·055	14	·000	13	+·026	13	+·032	14	...	+·039	41	+·029	+·033
1876	+·071	10	+·004	20	+·035	13	+·028	22	...	+·044	34	+·029	+·037
1877	+·004	6	+·005	13	+·053	13	+·015	15	...	+·034	28	+·022	+·026
1878	...		+·052	11	+·024	14	+·002	14	...	+·033	37	+·026	+·030
1879	...		+·038	9	+·005	12	+·006	12	...	+·054	26	+·016	+·032
1880	...		+·046	19	+·010	16	−·009	24	...	+·069	39	+·014	+·038

	T. L.		T.		C.		A. D.			Miscellaneous.		Mean of Assistants.	Mean of all.
	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.		s	No. of Obs.	s	s
1881	+·016	26	+·028	16	+·011	15	+·014	21	...	+·026	29	+·017	+·021
					H.								
1882	+·022	18	+·020	19	+·031	20	−·009	13	...	+·009	18	+·020	+·018
1883	+·030	19	−·014	23	+·026	17	+·017	20	...	+·020	34	+·013	+·015
1884	+·026	20	+·009	15	+·015	15	−·013	11	...	+·034	38	+·012	+·021
1885	−·003	20	+·009	16	+·029	25	−·012	16	...	+·007	38	+·006	+·006
1886	+·026	16	+·021	11	+·016	24	+·026	18	...	+·040	46	+·023	+·030
1887	+·031	17	+·018	17	+·008	21	+·009	19	...	+·019	51	+·016	+·017
1888	+·016	13	+·004	13	+·035	14	+·030	17	...	−·014	30	+·021	+·009
1889	+·032	14	+·023	12	+·032	19	+·049	19	...	+·020	43	+·034	+·028
1890	−·001	23	+·069	11	−·022	28	+·024	22	...	+·016	45	+·008	+·011
									A. C.				
									s No. of Obs.				
1891	+·024	15	+·051	12	+·031	21	+·074	9	+·019 16	+·027	43	+·033	+·031
			B.				T. H.						
1892	+·017	19	−·013	22	·000	9	−·011	15	+·013 31	+·038	40	+·003	+·013
1893	−·008	9	+·020	28	+·008	29	+·029	11	+·014 27	+·055	63	+·013	+·029
									Mean			+·022	

Tables IV., V., and VI. are in every way similar to tables I., II., and III., only referred to the Washington observations.

TABLE IV.

Washington Observations.—Corrections to Tabular R.A.'s of Sun from the American Ephemeris.

	E.		Hn.		Sk.		F.		S.		Mean.	
	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.
1872	−·069	36	...		...		+·028	25	+·008	20	−·020	81
1873	−·001	24	+·023	8	+·010	3	+·013	18	−·018	8	+·004	62
1874	−·042	25	...		+·116	23	+·094	14	−·033	16	+·031	78
			P.									
1875	+·006	25	+·039	16	+·042	26	+·030	24	+·117	3	+·031	94
1876	−·025	24	−·051	27	−·003	22	+·098	20	...		−·001	93
1877	−·012	14	−·039	12	+·021	15	+·102	10	...		+·014	51
									Pr.			
1878	−·035	10	−·057	11	+·013	17	+·043	12	−·011	7	−·006	57
1879	−·030	1	+·013	7	+·030	19	+·096	19	+·081	24	+·063	70
							R.		W.			
1880	−·029	12	−·026	7	+·021	16	+·008	10	+·010	16	+·001	61
1881	−·046	15	...		+·027	12	+·003	29	+·027	22	+·004	78
1882	−·049	13	...		+·047	13	−·044	16	+·014	35	−·003	77
1883	−·028	19	−·043	3	+·041	17	−·076	16	+·008	11	−·017	66
1884	−·037	26	−·032	24	+·042	22	...		+·025	26	−·002	98
1885	−·032	20	−·027	12	−·003	19	...		−·003	29	−·014	80
1886	−·024	22	+·001	15	+·006	23	...		+·042	18	+·005	78
1887	−·046	14	−·027	17	+·014	27	...		+·028	20	−·002	78

The initials E., Hn., Sk., F., S., P., Pr., R., and W. refer to Professors Eastman and Holden, Messrs. Skinner, Frisby, Stone, Paul, Pritchett, Rock, and Winlock.

TABLE V.

Corrections to reduce Tabular Corrections of R.A. of Sun to E. as standard.

	s		s
Hn.—E. =	−·024	Sk.—E. =	−·064
P.—E. =	−·001	Pr.—E. =	−·096
S.—E. =	−·028	R.—E. =	−·012
F.—E. =	−·085	W.—E. =	−·056

TABLE VI.

Washington Observations.—Corrections to Tabular R.A.'s of Sun from the American Ephemeris (corrected to E.).

	E.		Hn.		Sk.		F.		S.		Mean.
	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s	No. of Obs.	s
1872	−·069	36	...		...		−·057	25	−·020	20	−·052
1873	−·001	24	−·001	8	−·054	3	−·072	18	−·046	8	−·030
1874	−·042	25	...		+·052	23	+·009	14	−·061	16	−·009
1875	+·006	25	+·038 P.	16	−·022	26	−·055	24	+·089	3	−·009
1876	−·025	24	−·052	27	−·067	22	+·013	20	...		−·033
1877	−·012	14	−·042	12	−·043	15	+·017	10	...		−·022
1878	−·035	10	−·058	11	−·051	17	−·042	12	−·107 Pr.	7	−·055
1879	−·030	1	+·012	7	−·034	19	+·011	19	−·015	24	−·011
1880	−·029	12	−·027	7	−·043	16	−·004 R.	10	−·049 W.	16	−·033
1881	−·046	15	...		−·037	12	−·009	29	−·029	22	−·026
1882	−·049	13	...		−·017	13	−·056	16	−·042	35	−·042
1883	−·028	19	−·044	3	−·023	17	−·088	16	−·048	11	−·045
1884	−·037	26	−·033	24	−·022	22	...		−·031	26	−·030
1885	−·032	20	−·028	12	−·067	19	...		−·059	29	−·050
1886	−·024	22	·000	15	−·058	23	...		−·014	18	−·023
1887	−·046	14	−·028	17	−·050	27	...		−·028	20	−·038

The following table (VII.) contains the mean annual error of R.A. which was used in the discussions of the positions of the ecliptic for the various Greenwich Catalogues. The third column contains the annual mean error of R.A. of all the observations reduced to C. as a standard from Table III. Column 4 contains the corrections which have been or will be applied in the Greenwich Catalogues to the right ascensions of all stars. As a systematic error e was shown in the beginning of this Paper to affect the correction to the equinox directly, column 2 — column 1 is the correction required to column 3 to deduce the correction to the equinox corresponding to the R.A.'s of the Sun referred to C.

TABLE VII.

Year.	Annual Mean Error of R.A. (1)	Annual Mean Error of R.A. corrected to C.	Correction to Equinox. (3)	(3) corrected by (2−1).
	s	s	s	s
1864	+ 0·002	+ 0·030	−0·002	+ 0·026
1865	+ ·015	+ ·040	− ·010	+ ·015
1866	− ·013	+ ·008	− ·006	+ ·015
1867	− ·013	− ·006	− ·051	− ·044
1868	− ·005	+ ·028	− ·058	− ·025
1869	+ ·006	+ ·036	− ·001	+ ·029
1870	+ ·007	+ ·026	− ·012	+ ·007
1871	+ ·020	+ ·034	+ ·044	+ ·058
1872	+ ·002	+ ·005	− ·019	− ·016
1873	+ ·036	+ ·030	+ ·058	+ ·052
1874	+ ·051	+ ·040	− ·049	− ·060
1875	+ ·054	+ ·033	+ ·038	+ ·017
1876	+ ·044	+ ·037	+ ·055	+ ·048
1877	+ ·030	+ ·026	+ ·044	+ ·040
1878	+ ·050	+ ·030	− ·049	− ·069
1879	+ ·043	+ ·032	+ ·025	+ ·014
1880	+ ·060	+ ·038	− ·092	− ·114
1881	+ ·049	+ ·021	− ·035	− ·063
1882	+ ·036	+ ·018	− ·027	− ·045
1883	+ ·045	+ ·015	− ·002	− ·032
1884	+ ·056	+ ·021	+ ·084	+ ·049
1885	+ ·051	+ ·006	− ·009	− ·054
1886	+ ·066	+ ·030	+ ·094	+ ·058
1887	+ ·051	+ ·017	− ·046	− ·080
1888	+ ·042	+ ·009	+ ·072	+ ·039
1889	+ ·064	+ ·028	+ ·024	− ·012
1890	+ ·047	+ ·011	+ ·093	+ ·057
1891	+ ·070	+ ·031	+ ·088	+ ·049
1892	+ ·078	+ ·013	+ ·040	− ·025
1893	+ ·086	+ ·029	+ ·090	+ ·033

These new values, while showing more accordance, are only roughly corrected, as of course, properly speaking, each observation should be corrected for personality before the monthly means are formed.

From 1887–91 the correction to the equinox is now + ^{s}·011 instead of + ^{s}·043, but the correction to the Ten-Year Catalogue, 1880, is now − ^{s}·025 instead of + ^{s}·003. This result is doubtless

due partly to the roughness of the method of correction, and partly to the existence of periodic errors in the N.P.D.'s, pointed out above.

From 1864–69 the right ascensions of the stars depend on the equinox of the 1860 Catalogue, from 1870–77 on that of the 1864 Catalogue, from 1878–88 on that of the 1872 Catalogue, and from 1889 on that of the 1880 Catalogue, which is the same as that for 1872.

Catalogue.	Correction to Equinox.
1861	$-^{s}\cdot 01 \times \frac{5}{7}$
1864	$-^{s}\cdot 01$
1872	$+^{s}\cdot 007$
1880	$^{s}\cdot 000$

In order to reduce the right ascensions of the regular assistants referred to C. to the equinox of the Ten-Year Catalogue, 1880, for comparison with the Washington observations, we have applied a correction of $-^{s}\cdot 003$ to the years 1864–69, and $+^{s}\cdot 007$ to the years 1870–77.

Before we can directly compare the results of the Greenwich and Washington observations referred respectively to C. and E., it will be necessary to find the corrections required to reduce the tables of Hansen and Olufsen to those of Le Verrier. For this purpose we have taken the N.A. and A.E. places given for the Sun on the fifteenth day of each month as representing the mean monthly R.A.'s of observation, and tabulated the differences as corrections to the American Ephemeris (A.E.).

Table VIII.

Comparison between the Tables of the Sun for the 15th day of each month of the years 1872–87, as given by the Greenwich and American Nautical Almanacs.

R.A.

	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887
	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Jan. 15	+·05	+·08	+·05	+·02	·00	+·07	+·04	+·02	+·06	+·04	+·04	+·03	+·01	+·08	+·04	+·03
Feb. 15	+·01	+·03	−·01	+·02	−·01	+·03	+·05	·00	+·02	+·03	+·01	+·03	+·02	+·04	+·06	+·02
Mar. 15	·00	+·02	−·02	+·04	+·01	+·01	+·05	·00	+·01	+·04	−·02	+·03	+·03	+·02	+·05	·00
Apr. 15	+·03	+·01	−·04	+·05	+·01	+·01	+·04	+·02	+·02	+·03	·00	+·04	+·04	+·01	+·07	+·03
May 15	+·09	·00	−·02	+·06	+·03	+·05	+·03	+·04	+·08	+·03	−·01	+·07	+·05	+·04	+·05	+·06
June 15	+·08	+·04	+·04	+·05	+·03	+·12	+·06	+·03	+·08	+·05	+·04	+·06	+·07	+·09	+·07	+·05
July 15	+·07	+·02	+·05	+·06	+·03	+·10	+·06	+·05	+·07	+·04	+·07	+·06	+·02	+·08	+·05	+·05
Aug. 15	+·09	·00	+·04	+·09	+·02	+·05	+·06	+·10	+·08	+·02	+·04	+·06	+·01	+·05	+·07	+·06
Sept. 15	+·05	+·02	+·01	+·04	+·07	+·05	+·06	+·08	+·06	+·04	+·03	+·07	+·05	+·03	+·05	+·06
Oct. 15	+·05	+·06	+·02	+·02	+·04	+·05	+·08	+·07	+·05	+·06	+·03	+·02	+·05	+·03	+·04	+·03
Nov. 15	+·01	+·07	+·05	+·01	+·07	+·05	+·09	+·08	+·03	+·08	+·08	+·01	+·06	+·02	+·05	+·05
Dec. 15	+·04	+·09	+·10	+·03	+·09	+·08	+·11	+·10	+·05	+·06	+·09	+·05	+·07	+·05	+·06	+·06
Mean	+·048	+·037	+·023	+·041	+·033	+·056	+·061	+·049	+·051	+·043	+·033	+·044	+·040	+·045	+·055	+·042

These tables show a range in any year of about $0^s{\cdot}1$, and a constant difference of about $0^s{\cdot}05$. Before the correction to the equinox from the Greenwich and Washington observations can be properly compared, corrections should be applied for these monthly differences of tables. Roughly, the effect would be that of the mean for the year.

In the following table (IX.) we have converted the Washington corrections to the ephemeris of the Sun into tabular errors by changing the signs; the sum of the two columns 2 and 3 will then give in column 4 the Washington observed tabular errors of the Sun referred to Le Verrier's tables. The mean difference between the Greenwich and Washington results for the years 1872–87 ($-{}^s{\cdot}051$) may be considered as the probable value of the personality of Professor Eastman referred to Mr. Criswick.

Correcting the Washington observations by this amount, we then have them in a form which we can directly compare with those made at Greenwich. For this purpose we have used only those Greenwich observations made by the regular observers, after applying to them the small correction for a uniform equinox mentioned above.

TABLE IX.

Year.	Washington Tabular Errors of Sun in R.A. referred to E. as Standard (1).	Correction for Le Verrier's Tables (2).	Washington Tabular Errors of Sun in R.A. referred to Le Verrier's Tables and to E. as Standard.	Washington Tabular Errors of Sun in R.A. referred to Le Verrier's Tables and to C. as Standard.	Greenwich Tabular Errors of Sun in R.A. referred to C. and corrected to Equinox of the Ten-Year Catalogue, 1880.
	s	s	s	s	s
1864	...	...	...	...	+·025
1865	...	...	...	...	+·049
1866	...	...	...	...	·000
1867	...	...	...	...	+·002
1868	...	...	...	...	+·019
1869	...	...	...	...	+·044
1870	...	...	...	...	+·037
1871	...	...	...	...	+·027
1872	+·052	+·048	+·100	+·049	+·018
1873	+·030	+·037	+·067	+·016	+·040
1874	+·009	+·023	+·032	−·019	+·065
1875	+·009	+·041	+·050	−·001	+·036
1876	+·033	+·033	+·066	+·015	+·036
1877	+·022	+·056	+·078	+·027	+·028
1878	+·055	+·061	+·116	+·066	+·026
1879	+·011	+·049	+·060	+·009	+·016
1880	+·033	+·051	+·084	+·033	+·014
1881	+·026	+·043	+·069	+·018	+·017
1882	+·042	+·033	+·075	+·024	+·020
1883	+·045	+·044	+·089	+·038	+·015
1884	+·030	+·040	+·070	+·019	+·012
1885	+·050	+·045	+·095	+·044	+·006
1886	+·023	+·055	+·078	+·027	+·023
1887	+·038	+·042	+·080	+·029	+·016
1888	...	...	...	...	+·021
1889	...	...	...	...	+·034
1890	...	...	...	...	+·008
1891	...	...	...	...	+·033
1892	...	...	...	...	+·003
1893	...	...	...	...	+·013

The following six tables deal with the N.P.D. observations at Greenwich and Washington exactly in the same manner as was done in the case of the R.A.'s.

For Greenwich we have taken the years 1881–93 only, as they are in all respects strictly comparable; and as T. L. observed continuously throughout this period, we have taken him as our standard. For Washington we have taken the same period as in the R.A. observations, and referred them to E.

TABLE X.

Greenwich Mean Tabular Errors of N.P.D. of Sun (mean of both limbs only).

	T. L.	No. of Obs.	T.	No. of Obs.	C.	No. of Obs.	A. D.	No. of Obs.		Miscell.	No. of Obs.	Mean.
	"		"		"		"			"		"
1881	+·01	24	+·52	17	+·29	15	−·31	23	...	+·29	29	+·13
					H.							
1882	+·47	17	+·55	21	+·87	25	+·07	13	...	+·50	21	+·55
1883	−·55	22	+·19	23	+·22	20	−·54	21	...	−·14	37	+·16
1884	−·58	20	−·39	15	−·01	15	−·81	15	...	−·18	37	−·35
1885	−·55	20	+·02	18	+·06	28	−·51	18	...	−·29	40	−·23
1886	+·12	17	−·19	11	+·51	28	−·23	23	...	−·26	50	−·03
1887	−·17	18	+·09	21	+·44	26	−·15	19	...	+·33	55	+·18
1888	+·55	16	−·19	17	+·52	15	−·66	16	...	+·09	32	+·16
1889	+·40	17	+·17	13	+·31	19	+·03	24	...	+·09	46	+·16
1890	+·11	23	−·26	11	+·06	30	−·31	23	...	+·05	52	−·02
									A. C.			
1891	+·50	15	+·04	15	+·16	22	−·54	13	−·17	18	+·17	44 +·07
			B.				T. H.					
1892	+·78	21	+·14	21	+·60	10	+1·19	15	+·31	32	−·07	46 +·34
1893	+·16	10	+·01	27	−·16	31	+·92	11	−·12	28	+·18	66 +·09

TABLE XI.

Corrections to reduce Table X. to T. L. as standard.

A. D.—T. L. = −0".33
T.—T. L. = +0·09
H.—T. L. = +0·20
A. C.—T. L. = −0".52
B.—T. L. = −0·50
T. H.—T. L. = +0·49
Misc. = +0·05

TABLE XII.

Greenwich Mean Tabular Errors of Sun in N.P.D. referred to T. L. as standard.

	T. L.	T.		A. D.		Miscell.	Mean of Assistants.	Mean of all.
	No. of Obs.	No. of Obs.	No. of Obs.	No. of Obs.		No. of Obs.	No. of Obs.	
	"	"	"	"		"	"	"
1881	+·01 24	+·43 17	...	+·02 23	...	+·24 29	+·12 64	+·16
			H.					
			"					
1882	+·47 17	+·46 21	+·67 25	+·40 13	...	+·45 21	+·52 76	+·51
1883	−·55 22	+·10 23	+·02 20	−·21 21	...	−·19 37	−·12 86	−·14
1884	−·58 20	−·48 15	−·21 15	−·48 15	...	−·23 37	−·45 65	−·31
1885	−·55 20	−·07 18	−·14 28	−·18 18	...	−·34 40	−·22 84	−·26
1886	+·12 17	−·28 11	+·31 28	+·10 23	...	−·31 50	+·13 79	−·04
1887	−·17 18	·00 21	+·24 26	+·18 19	...	+·28 55	+·08 84	+·16
1888	+·55 16	−·28 17	+·32 15	−·33 16	...	+·04 32	−·03 64	−·01
1889	+·40 17	+·08 13	+·11 19	+·36 24	...	+·04 46	+·26 73	+·17
1890	+·11 33	−·35 11	−·14 30	+·02 23	...	·00 52	−·04 97	−·03
					A. C.			
					No. of Obs.			
					"			
1891	+·50 15	−·05 15	−·04 22	−·21 13	+·35 18	+·12 44	+·12 82	+·12
		B.		T. H.				
1892	+·78 21	+·64 21	+·40 10	+·70 15	+·83 32	−·12 46	+·71 99	+·43
1893	+·16 10	+·51 27	−·36 31	+·43 11	+·40 28	+·13 66	+·28 107	+·22

TABLE XIII.

Washington Corrections to Tabular N.P.D.'s of Sun from the American Ephemeris (mean of both limbs only).

	E.	No. of Obs.	Sk.	No. of Obs.	F.	No. of Obs.	Hn.	No. of Obs.	S.	No. of Obs.	Mean.	No. of Obs.
	"		"		"		"		"		"	
1872	−0·50	35	...		−0·42	21	...		−0·01	17	−0·37	73
1873	+0·86	24	...		−0·08	19	+0·85	11	+1·27	10	+0·67	64
1874	−0·21	26	+0·56	24	−0·74	16	...		+0·42	14	+0·02	80
							P.					
1875	+1·33	24	+0·80	26	+0·82	21	+1·30	16	...		+1·04	87
1876	+0·39	27	+0·59	24	−0·22	22	+0·53	29	...		+0·35	102
									Pr.			
1877	+1·48	15	+1·45	15	+0·70	12	+0·81	11	...		+1·16	53
1878	−0·49	11	+0·14	18	+0·01	11	−0·31	11	−0·23	8	−0·14	59
1879	+0·09	1	+1·83	17	+0·07	18	+1·61	7	+1·45	27	+1·20	70
					W.				R.			
1880	+1·32	13	+1·13	16	+2·91	12	+2·10	5	+1·56	8	+1·73	54
1881	+1·47	15	+1·46	12	+1·57	23	...		+1·22	32	+1·40	82
1882	−0·02	13	+0·55	10	+0·50	31	...		+0·22	18	+0·34	72
1883	+1·87	20	+1·47	18	+1·95	14	+0·37	3	+1·89	15	+1·72	70
1884	+0·66	25	+1·42	23	+1·31	28	+0·43	24	...		+0·96	100
1885	+0·65	24	+0·89	20	+1·58	31	+0·17	12	...		+0·97	87
1886	−0·35	24	+0·37	23	+0·68	17	+0·31	15	...		+0·20	79
1887	+0·48	14	+0·65	28	+0·38	22	−0·12	17	...		+0·39	81

TABLE XIV.

Corrections to reduce Table XIII. to E. as standard.

F.—E. = +0·42	S.—E. = −0·31
Hn.—E. = +0·01	R.—E. = +0·10
Sk.—E. = +0·19	W.—E. = −0·51
Pr.—E. = −1·44	P.—E. = +0·19

TABLE XV.

Washington Observations.—Corrections to Tabular N.P.D.'s of Sun from the American Ephemeris referred to E. as standard.

	E.		Sk.		F.		Hn.		S.		Mean.	
	"	No. of Obs.	"	No. of Obs.	"	No. of Obs.	"	No. of Obs.	"	No. of Obs.	"	No. of Obs.
1872	−0·50	35	...		0·00	21	...		−0·32	17	−0·31	73
1873	+0·86	24	...		+0·34	19	+0·86	11	+0·96	10	+0·88	64
1874	−0·21	26	+0·37	24	−0·32	16	...		+0·11	14	0·00	80
							P.					
1875	+1·33	24	+0·61	26	+1·24	21	+1·49	16	...		+1·12	87
1876	+0·39	27	+0·40	24	+0·20	22	+0·72	29	...		+0·44	102
1877	+1·48	15	+1·26	15	+1·12	12	+1·10	11	...		+1·23	53
									Pr.			
1878	−0·49	11	−0·05	18	+0·43	11	−0·12	11	−1·67	8	−0·08	59
1879	+0·90	1	+1·64	17	+0·49	18	+1·80	7	+0·01	27	+1·27	70
					W.				R.			
1880	+1·32	13	+0·94	16	+2·40	12	+2·29	5	+1·66	8	+1·52	54
1881	+1·47	15	+1·27	12	+1·06	23	...		+1·32	32	+1·13	82
1882	−0·02	13	+0·36	10	−0·01	31	...		+0·32	18	+0·10	72
1883	+1·87	20	+1·28	18	+1·44	14	+0·56	3	+1·99	15	+1·56	70
1884	+0·66	25	+1·23	23	+0·80	28	+0·62	24	...		+0·76	100
1885	+0·65	24	+0·70	20	+1·08	31	+0·36	12	...		+0·77	87
1886	−0·35	24	+0·18	23	+0·17	17	+0·50	15	...		+0·08	79
1887	+0·48	14	+0·46	28	−0·13	22	+0·07	17	...		+0·22	81

In order to compare the tables employed in the English and American *Nautical Almanacs*, we append a table (XVI.) for the N.P.D.'s similar to Table VIII. for the R.A.'s.

TABLE XVI.

Comparison between the Tables of the Sun for the Fifteenth Day of each Month of the Years 1872–87 as given by the Greenwich and American Nautical Almanacs.

N.P.D.

	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887
	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″
Jan. 15	0·0	0·0	0·0	+0·2	+0·4	0·0	0·0	+0·1	+0·1	−0·1	+0·1	+0·1	−0·2	−0·1	−0·1	0·0
Feb. 15	−0·1	−0·2	−0·1	0·0	+0·1	−0·1	−0·2	−0·1	+0·1	−0·2	+0·1	+0·1	0·0	−0·2	−0·2	0·0
Mar. 15	−0·3	−0·2	−0·1	−0·3	0·0	−0·2	−0·4	−0·2	+0·1	−0·3	+0·1	−0·2	0·0	−0·3	−0·2	0·0
Apr. 15	−0·3	−0·3	+0·1	−0·3	−0·1	+0·1	−0·3	−0·2	−0·2	−0·3	0·0	−0·5	−0·2	−0·3	−0·4	−0·3
May 15	−0·2	−0·2	−0·2	−0·4	−0·2	−0·3	−0·1	−0·3	−0·3	−0·2	−0·1	−0·5	−0·1	−0·4	−0·2	−0·4
June 15	−0·4	−0·2	−0·2	−0·2	−0·3	−0·3	−0·2	−0·2	−0·2	−0·1	+0·1	−0·2	−0·3	−0·2	−0·1	−0·3
July 15	−0·1	−0·3	0·0	−0·1	0·0	+0·1	0·0	0·0	+0·1	−0·1	+0·1	+0·1	−0·1	0·0	+0·1	0·0
Aug. 15	+0·2	−0·2	+0·1	+0·3	+0·1	+0·2	+0·2	+0·3	+0·3	−0·2	+0·2	+0·3	0·0	+0·1	+0·3	+0·2
Sept. 15	+0·2	+0·3	−0·1	+0·4	+0·4	+0·4	+0·6	+0·6	+0·3	+0·4	+0·3	+0·3	+0·2	+0·3	+0·2	+0·6
Oct. 15	+0·1	+0·6	+0·1	+0·2	+0·5	+0·3	+0·4	+0·5	+0·3	+0·4	+0·3	+0·2	+0·5	+0·2	+0·1	+0·6
Nov. 15	+0·1	+0·5	+0·4	+0·1	+0·4	+0·6	+0·4	+0·3	+0·2	+0·4	+0·3	+0·1	+0·4	+0·3	+0·1	+0·3
Dec. 15	−0·1	+0·2	+0·3	0·0	+0·2	+0·4	+0·1	−0·1	0·0	+0·2	+0·1	−0·1	0·0	+0·2	+0·1	+0·1
Means	−0·08	0·0	+0·03	−0·01	+0·13	+0·10	+0·04	+0·06	+0·07	−0·01	+0·13	−0·03	+0·02	−0·03	−0·03	+0·07

It is apparent from these tables that there is a considerable amount of personality among the different observers in determining the position of the centre of the Sun in N.P.D., but the effects are not so general as in the case of the R.A. ; we have only exhibited them here to show their existence, for which there does not appear to be any reasonable cause, as there is little or no motion in the direction of measurement, and otherwise the conditions are nearly the same for both limbs. The still large remaining discordances in the correction to the equinox, after allowing for the personality of observers in making R.A. observations, and considering the apparently small mean annual error in the N.P.D. Greenwich observations, appear to suggest some periodical error in the tables or observations, which may form, we hope, the subject of a future communication.

Photograph of the Nebulæ M 78 *and* H IV. 36 *Orionis.*

By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebulæ M 78 and H IV. 36 *Orionis*, R.A. 5^h 41^m, Decl. 0° 1′ north, was taken with the 20-inch reflector on 1894 January 28, with exposure of the plate during three hours, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The nebulæ are Nos. 2,068 and 2,071 in the *New General Catalogue*, and Nos. 1,267, 1,270 in the *General Catalogue*.

The nebula M 78 (*N. G. C.* No. 2,068) is described by Sir J. Herschel as bright, large, wispish, very gradually much brighter in the middle, three stars involved, barely resolvable. In the *Phil. Trans.* 1833, pl. xii., fig. 36, a drawing of it is given which, in outline, resembles the central part of the nebulosity. The nebula H IV. 36 (*N. G. C.* No. 2,071) is described as a star with very faint large *chevelure*.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, p. 51) gives the results of nine observations made between the years 1850 and 1877, and states that a "spiral arrangement is sufficiently seen to confirm former observations." A marginal sketch is given, and a drawing on pl. i., fig. 5 ; but they are not like the photograph, and they quite fail to indicate the form of the nebula as it is there shown.

The photograph shows the central part of the nebula as a dense cloud with a well-defined margin on the n.p. side, and the three stars referred to by Herschel and Rosse are shown involved in the nebulosity. The star on the northern edge has a faint companion, and faint star-like condensations are also seen involved in the nebulosity. There are flocculent clouds of nebulosity surrounding the dense central part, with wide dark spaces between them, which the descriptive matter and the drawings by Sir J. Herschel and Lord Rosse fail to indicate.

The nebula H IV. 36 (*G. C.* 1,270) has a stellar nucleus, with a small companion star close to it on the south side, and this double nucleus is surrounded by cloud-like streaky nebulosity.

The distance between the centres of the nebulæ is about 15 minutes of arc, and there are indications that the two nebulæ are connected together with very faint nebulosity, but there is no spiral form (as suggested by Lord Rosse) visible in either of them.

The sky within a radius of about half a degree of these nebulæ is remarkably void of stars, but beyond this distance, both *preceding* and *following*, the stars are crowded on the plate.

Photograph of the Nebula M 74 *Piscium.*

By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebula M 74 *Piscium*, R.A. $1^h\ 31^m$, Decl. 15° 15′ north, was taken with the 20-inch reflector on 1893 December 9, with exposure of the plate during three hours and forty minutes, and the copy now presented is enlarged to the scale of 1 millimetre to 15 seconds of arc.

The nebula is No. 628 in the *New General Catalogue* and 372 in the *General Catalogue*.

Sir J. Herschel (*G. C.* 372, p. 52) states as the result of eleven observations that it is a globular cluster, faint, very large, round, pretty suddenly much brighter in the middle, partially resolved.

Lord Rosse (*Phil. Trans.* 1861, p. 711) designates it as a spiral nebula with the centre formed of stars, and several stars visible through the nebula. A marginal sketch shows the spiral form, and in the *Observations of Nebulæ and Clusters of Stars*, p. 21, another marginal sketch is given which shows a nucleus and five stars involved in the spirals.

The photograph shows the nebula to be a very perfect spiral, with a central stellar nucleus and a 15th mag. star close to it on the south side. The convolutions of the spiral are studded with many stars and star-like condensations, and on the *north preceding* side there is a partial inversion of one of the convolutions, which conveys the idea of some irregular disturbing cause having interfered with the regular formation of a part of that convolution.

The photograph cannot be adequately described, it must be examined before it can be fully appreciated.

Note on the Solar Eclipse of 1598. By J. L. E. Dreyer, Ph.D.

On 1598 February 25 (March 7) an eclipse of the Sun took place which was extensively observed in Germany. At that time Tycho Brahe, who had left Denmark in the previous summer, was staying at Wandsbeck in Holstein, close to Hamburg, and observed the eclipse there. His assistant, Longomontanus, observed it at Rostock, and a former assistant, Christen Hansen, observed it in Jutland. It is, however, more interesting that the eclipse was watched at the deserted observatory on the island of Hveen with one of the four great instruments which had been left behind on Tycho's departure from the island, and which were not removed till towards the end of 1599. As I had last year an opportunity of examining the particulars of this observation in the original MS. volume of observations from the year 1598, in the Royal Library of Copenhagen, a short account of it may not be uninteresting to the Society, particularly as some writers seem to have doubted that the eclipse was actually observed at Hveen.

In a letter to Magini, dated from Dresden 1598 November 28,* Tycho gives the following particulars about this eclipse :

"Martii d. 6. Eclipsis ⊙ medium 11^h 5′ a.mn. Uraniburgi in Dania. Magnitudo Eclipsationis ibidem apparuit a parte superiori intra 9 et 10 digitos."

He adds that all this agrees well with his own tables. In another letter to Magini from Prague, of 1601 January 24,† Tycho again alludes to this eclipse as having been observed at Uraniborg with one of the instruments left there. He refers for details to a paper enclosed in the letter, but this paper appears to have been lost. Some further particulars are, however, given in a letter to Kepler of 1599 December 9.‡ In this Tycho first states that according to his own tables the magnitude of the eclipse should be 9½ digits, and continues : "qua etiam quantitate Sol deficere a quodam ex meis Uraniburgi isthic (ut 4 residuorum instrumentorum, quae prae magnitudine efferri tam cito nequibant, curam haberet) relicto studioso deprehensus est, et tempora alias per armillam aequatoriam, 18 pedum in diametro, a principio usque ad finem (fuit enim toto isthic tempore serenum) meae restitutioni apprime congruentia coelitus denotata sunt, quae erant ejuscemodi, ut deliquium inciperet isthic h. 10.10′, finem haberet h. 12.19′, ideoque medium existeret h. 11.12′."

In his book on optics (*Paralipomena in Vitellionem*, cap. xi.) Kepler discusses the observations of this eclipse, and states that it was by a student of Tycho's observed to commence at 10^h 3^m and to end at 12^h 32^m, the duration being 2^h 29^m. In the *Tabulae Rudolphinae* (pp. 110, 111) this eclipse is used as an

* *Carteggio inedito di Ticone Erahe . . . con G. A. Magini*, p. 222.
† *Ibid.* p. 238.
‡ *Opera Omnia*, ed. Frisch, i. 225.

example of the method for computing an eclipse for a particular locality, and it is shown that it lasted $2^h\ 21^m$. Kepler adds that the longer duration given in his *Optics* was erroneous: "Quin etiam addita observatio, tanquam Uraniburgica, quamvis neque Tychonis sit, qui tunc insula excesserat, nec Uraniburgica omnino, durationem tamen tantam convellit. Apparet enim ex fine h. 12.32′, observationem esse Origani Frankofurdiani ad Oderam, qui hunc finem annotat: initium autem expressit sic: h. $10\frac{1}{3}$, quod alius superveniens legit h. 10.3′."

Did Kepler, then, when writing this, believe that the eclipse had *not* been observed at Uraniborg? It almost seems so, and Frisch evidently is of this opinion when using the expression, "De observatore Huennensi, seu potius Francofurtensi, vide annotationem sequentem," before reprinting the sentences quoted above.* And yet Kepler might easily have satisfied himself that the figures given in his *Optics* were not those deduced by Tycho from the observation made at Hveen, as Tycho's manuscripts were in his possession, though possibly he had not all of them at hand when writing the text to the *Tabulae Rudolphinae*.

In the MS. volume containing Tycho's original observations made during the years 1598 and 1599 the account of the observations made at Hveen is headed: "Eclipsis Solis Anni 1598 Mense Feb. die 25 Vraniburgi obseruata." Then follow sixteen diagrams of the solar disc with some figures beside each, which evidently represent the corresponding hour angles of the Sun. The first diagram shows that the Moon has already entered on the solar disc some five or six minutes before, as more than a tenth part of the solar diameter is eclipsed, and next it is written: "Tunc fuit Sol orienta. $26^g\ 25^m$, H. 10 $14\frac{1}{2}$," underneath which is written in Tycho's own hand: "Pone initium 28 graduum." At the following diagrams the hour angles are only given in degrees and minutes, not in time; and after the second one Tycho has written: "Sic Tycho . . . initium 10.10" (the dots represent an illegible word). The fourteenth diagram shows that the last contact is close at hand, and next it is written: "Sol occidentalis $\overset{4\ \ 40}{0^H\ 18^M}$" to which Tycho adds: "Tycho fecit finem 12.19." Diagrams 15 and 16 are only blank circles with the hour angles 7.15 and 7.20, showing that the eclipse was over. The whole account occurs also in a quarto volume which contains copies (not originals) of observations made in 1593, 1590, and 1598–1600,† the only difference being that Tycho's concluded times of beginning and end of the eclipse are not given in this volume.

* *Opera Omnia*, ii. 441.

† This volume is numbered "1828, 4to," see my *Tycho Brahe*, p. 391, footnote 3. Probably the first part of the volume, containing observations made in 1593, has belonged to the set of quarto volumes used by Albert Curtz for the compilation of the well-known *Historia Coelestis*, as the year 1593 is omitted in the latter.

All this is in perfect accordance with the particulars quoted above from Tycho Brahe's letter to Kepler of 1599 December 9, and if the figures given by Kepler in the *Paralipomena* were copied from Origanus, this mistake was Kepler's own, and not Tycho's, as the latter concluded from the diagrams made at Uraniborg that the eclipse began for that place at $10^h\ 10^m$ and ended at $12^h\ 19^m$.

Note on the Proper Motion of the Star L L 38239.

By J. L. E. Dreyer.

The magnitude of this star is given as 7·6 in the *Durchmusterung*, and it follows about 1^m after the Dumb Bell Nebula. I am not aware that the Proper Motion has been noticed before. The following positions are for 1890·0 and are referred to Auwers' fundamental system; Lalande's and Bessel's observations have been reduced anew by Asten's and Luther's tables.

	h	m	s	°	′	″		
Lalande 38239	19	55	58·35	+22	25	25·5	(1 obs.)	1796·6
Bessel (W. 1792)			58·72			13·1	(1 obs.)	1825·7
Rümker 7900			58·63			8·3	(4 obs.)	1840
Bonn (Beob. Bd. vi.)			58·79			3·8	(3 obs.)	1862·6
Berlin Zone			58·76		24	59·4	(2 obs.)	1881·7
Copenhagen, Pechüle			58·79			56·5	(2 obs.)	1893·7

The last observation was kindly made at my request. Lalande has two wire-transits in good accordance *inter se*. A proper motion $= +0^s{\cdot}0032$ and $-0''{\cdot}252$ represents these observations as follows:—

	h	m	s	°	′	″
Lalande	19	55	58·65	+22	24	62·0
Bessel			58·92			56·9
Rümker			58·79			55·7
Bonn			58·88			56·9
Berlin			58·79			57·3
Copenhagen			58·78			57·4

Armagh Observatory,
1894 *May.*

A New Variable Star of Type IV. By the Rev. T. E. Espin, M.A.

On the night of 1893 September 16, while sweeping on the confines of *Lyra* and *Cygnus*, I came upon a fine red star which was found to be missing in *Argelander*. The place of this star for 1855 is

R.A. $19^h\ 15^m\ 2^s{\cdot}7$ Decl. $+37°\ 36'\ 6$

The place depending on D.M. $+37°{\cdot}3420$.

The following are my observations of the star :—

1893 Sept. 16, Mag. 9·0

Nov. 13, Mag. 9·0

On the first of these nights the spectrum was believed to be Type IV., but its faintness made me feel some uncertainty about it. On March 29 I set for this star in strong twilight, and was at once struck by its increased brilliancy. I rated it 8·3, and found the bands quite obvious, even in the dawn. On April 10 I set for it again, and rated it 8·5. The spectrum was found to be Type IV., but band No. 9 of Dunér's nomenclature is of such a size and intensity as to cause the spectrum to appear a mere fragment. With careful attention I could make out band No. 6, but as faint as No. 9 was strong. The first appearance of the spectrum was unique, as it appeared continuous, but with the least refrangible end completely absorbed. The telescope was turned immediately afterwards upon *Es-Birm* 608, a fourth-type star, somewhat brighter, and the contrast with the perfectly normal Type IV. spectrum was very striking. Unfortunately a temporary derangement of the second spectroscope prevented fuller observation.

Towlaw, Darlington:
1894 *April* 11.

Note on the Red Spot of Jupiter. By Joseph Gledhill, Bermerside Observatory, Halifax.

This object was carefully observed whenever seen on the disc. The whole outline was never steadily seen between 1893 January and 1894 March. No trace of colour was ever seen within the faint elliptic outline. Sometimes the following end of the ellipse was better seen than the preceding end ; at other times the two ends appeared stronger than the middle part. The best view was obtained on 1893 December 23, when the whole outline was distinctly seen at moments of best definition ; the spot was then not far from the western limb. It was last seen on 1894 February 9, as a very faint elliptic outline without colour.

Observations of the Phenomena of Jupiter's Satellites at Bermerside Observatory, Halifax, in the years 1892 *and* 1893. By Joseph Gledhill.

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	*N. Almanac* Time.	Remarks.
1893.				h m s	h m s	
Jan. 2	III.	Tr. I.	Ext. contact.	8 40	8 39	Definition poor.
			Bisection.	8 43 30		
			Int. contact.	8 46 45		
4	I.	Oc. D.	Ext. contact.	6 21 10	6 22	Misty.
			Bisection.	6 23 14		
			Just gone.	6 25 7		
	I.	Ec. R.	First seen.	9 54 41	9 54 15	Very misty; planet low.
			Half out?	9 56		
			Full?	9 59		
13	I.	Ec. R.	First seen.	6 19 14	6 18 58	Often cloudy.
			Half out?	6 21		
			Full?	6 23		
	III.	Ec. D.	Last seen.	8 25 2	8 23 13	
	III.	Ec. R.	First seen.	10 7 32	10 11 39	Planet low; bad sky.
			Half out?	10 9		
			Full?	10 12 30		
14	II.	Tr. I.	Ext. contact.	7 16 27	7 18	Fair definition.
			Bisection.	7 17 30		
			Int. contact.	7 19 34		
16	II.	Ec. R.	First seen.	6 35 15	6 34 31	
			Half out?	6 37		
			Full?	6 40		
20	III.	Oc. D.	Ext. contact.	6 41 11	6 46	Fair definition.
			Bisection.	6 45 17		
			Last seen.	6 50 34		
	I.	Ec. R.	First seen.	8 14 36	8 14 44	
			Half out?	8 16		
			Full?	8 19		
	III.	Oc. R.	Bisection.	9 10 14	9 16	Planet low; bad definition.
			Ext. contact.	9 13 17		
27	I.	Oc. D.	Ext. contact.	6 42 13	6 43	Poor definition.
			Last seen.	6 45 9		

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation. h m s	*N. Almanac* Time. h m s	Remarks.
1893.						
Feb. 5	I.	Ec. R.	First seen.	6 35 38	6 35 1	
			Half out?	6 38		
			Full?	6 41		
8	II.	Sh. I.	First seen.	7 13	7 14	Windy, cloudy, much motion.
			Int. contact.	7 15 19		
	II.	Tr. E.	Int. contact.	7 18 4	7 22	
			Ext. contact.	7 25 10		
11	I.	Tr. I.	Ext. contact.	7 51 8	7 50	Much boiling on limb of planet.
			Bisection?	7 52 5		
			Int. contact.	7 55 9		
Aug. 14	I.	Tr. I.	Int. contact.	12 14	12 10	Planet very low in E.
	I.	Sh. E.	Int. contact.	12 59 14	12 59	
Sept. 11	II.	Ec. R.	First seen.	10 24 22	10 23 15	Planet very low; much motion.
			Half out?	10 27		
	II.	Oc. D.	Ext. contact.	10 46	10 45	
			Half gone?	10 47		
			Just gone?	10 48		
14	I.	Ec. D.	Fading.	10 0	10 1 41	Violent motion; planet low.
			Half gone?	10 1		
			Just gone.	10 2		
21	III.	Oc. D.	Ext. contact.	10 8	10 6	Much motion.
			Bisection.	10 15		
			Last seen.	10 20		
	III.	Oc. R.	First seen.	11 10	11 23	Bad definition.
			Bisection.	11 15		
			Ext. contact.	11 20		
	I.	Ec. D.	Fading.	11 53	11 55 43	Bad definition.
			Half gone.	11 55		
			Just gone.	11 56 15		
23	I.	Oc. R.	First seen.	9 44 30	9 45	Violent motion; clouds showery.
			Bisection.	9 45 30		
			Ext. contact.	9 46 30		
29	I.	Sh. I.	First seen.	11 8	11 8	
			Int. contact.	11 10		
Oct. 1	I.	Tr. E.	Ext. contact.	8 53	8 53	Planet very low; bad sky.
4	II.	Tr. I.	Ext. contact.	12 10 12	12 9	Definition bad.

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	*N. Almanac* Time.	Remarks.
1893.				h m s	h m s	
Oct. 4	II.	Tr. I.	Bisection.	12 12 37		
			Int. contact.	12 14 30		
6	II.	Oc. R.	Half out.	9 27	9 26	Planet low; much motion.
			Ext. contact.	9 29		
8	I.	Tr. I.	Ext. contact.	8 27	8 28	Planet very low.
			Int. contact.	8 30		
	I.	Sh. E.	Int. contact.	9 42 17	9 42	
			Just off.	9 44		
	I.	Tr. E.	Int. contact.	10 35	10 39	
			Bisection.	10 36		
			Ext. contact.	10 38 30		
16	I.	Oc. R.	Half out?	9 32	9 33	Stormy; bad definition.
			Ext. contact.	9 34		
	III.	Tr. I.	First contact.	10 43	10 45	Very difficult and uncertain observation. Sat. moved along south limb of planet.
			Bisection.	10 54		
			Quite on disc.	11 5		
	III.	Tr. E.	Half off.	11 48	11 57	As above; clouds.
22	II.	Tr. E.	Bisection.	8 13	8 13	Clouds.
Dec. 9	I.	Tr. I.	Ext. contact.	5 40	5 39	Good definition.
			Bisection.	5 42		
			Int. contact.	5 44		
	I.	Sh. I.	Int. contact.	6 13	6 11	
	II.	Ec. R.	First seen.	6 41 20	6 42 57	
			Half out?	6 44		
			Full?	6 48		
	I.	Tr. E.	Int. contact.	7 48 16	7 50	
			Bisection.	7 50 39		
			Ext. contact.	7 52 42		
	I.	Sh. E.	Int. contact.	8 20 27	8 23	
			Half off.	8 22 34		
15	I.	Oc. D.	Ext. contact.	10 8 12	10 9	Stormy.
			Half gone.	10 9 51		
			Just gone.	10 10 30		
16	III.	Ec. D.	Fading.	5 10	5 13 42	Often cloudy.
			Half gone?	5 12		
			Just gone.	5 16 25		

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation. h m s	*N. Almanac* Time. h m s	Remarks.
1893.						
Dec. 16	II.	Oc. D.	Ext. contact.	5 36	5 38	
	III.	Ec. R.	Half out?	6 48	6 49 40	Cloudy.
	I.	Tr. I.	Ext. contact.	7 26 43	7 23	
			Bisection.	7 27 17		
			Int. contact.	7 28 30		
	I.	Sh. I.	Int. contact.	8 7 19	8 6	
	II.	Ec. R.	First seen.	9 18 10	9 18 21	
			Half out?	9 20		
			Full?	9 23		
	I.	Tr. E.	Int. contact.	9 33 5	9 35	
			Bisection.	9 35 27		
			Ext. contact.	9 37 18		
17	I.	Ec. R.	First seen.	7 27	7 29 21	Clouds passing. The sat. had been out several seconds when first seen at $7^h\ 27^m$.
23	III.	Oc. R.	Half off?	7 18 7	7 27	A difficult observation, owing to way in which the sat. came off.
			Ext. contact?	7 26 12		
	II.	Oc. D.	Ext. contact.	7 55 14	7 56	Clouds passing.
			Bisection.	7 58 23		
			Just gone.	7 59 19		
	I.	Tr. I.	Ext. contact.	9 10 6	9 9	
			Bisection.	9 13 17		
			Int. contact.	9 15 42		
	III.	Ec. D.	Fading.	9 15	9 15 31	Clouds passing.
			Still visible.	9 17		
25	II.	Tr. E.	Ext. contact.	4 49	4 51	Bad definition; clouds passing.
			Bisection.	4 52		
	II.	Sh. E.	Int. contact.	6 38	6 37	Violent motion.
30	III.	Oc. D.	Ext. contact.	9 13 17	9 16	
1894.						
Jan. 1	I.	Sh. I.	Int. contact.	6 24 30	6 24	
	I.	Tr. E.	Int. contact.	7 32 18	7 36	
			Bisection.	7 34 6		
			Ext. contact.	7 37 15		
	I.	Sh. E.	Int. contact.	8 34 10	8 37	
	II.	Sh. E.	Int. contact.	9 10 47		Not given in *N. Almanac*.
2	I.	Ec. R.	First seen.	5 48 19	5 49 42	Hazy sky.

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	*N. Almanac* Time.	Remarks.
1894.				h m s	h m s	
Jan. 17	I.	Tr. E.	Int. contact.	5 39 16	5 43	
			Bisection.	5 42 21		
			Ext. contact.	5 45 17		
	III.	Tr. I.	Ext. contact.	6 26	6 27	Very difficult, owing to way in which sat. is moving. Times uncertain to at least 1m.
			Bisection.	6 33		
			Int. contact.	6 39		
	II.	Oc. R.	Ext. contact.	6 36	6 38	
	I.	Sh. E.	Int. contact.	6 51	6 56	Overcast; rain.
22	I.	Tr. I.	Ext. contact.	10 54	10 54	
			Int. contact.	10 58		
23	I.	Oc. D.	Ext. contact.	8 8 51	8 11	
			Bisection.	8 11 7		
			Just gone.	8 13 13		
	I.	Ec. R.	First seen.	11 36 58	11 37 17	
31	I.	Tr. I.	Ext. contact.	7 17 8	7 15	
			Bisection.	7 19 13		
			Int. contact.	7 21 10		
	I.	Sh. I.	Int. contact.	8 35 46	8 34	
	II.	Oc. D.	Ext. contact.	9 14 42	9 16	
			Bisection.	9 16 31		
			Just gone.	9 18 24		
	I.	Tr. E.	Int. contact.	9 25 27	9 28	
			Bisection.	9 27 16		
			Ext. contact.	9 29 18		
Feb. 2	II.	Tr. E.	Int. contact.	6 27 18	6 34	Stormy; raining.
			Bisection.	6 29 27		
			Ext. contact.	6 31 23		
4	III.	Oc. R.	Ext. contact.	5 51 24	5 53	Stormy; cloudy.
8	I.	Oc. D.	Ext. contact.	6 26 5	6 27	Stormy.
			Bisection.	6 28 14		
			Just gone.	6 30 18		
	I.	Ec. R.	First seen.	9 57 38	9 58 2	
			Half out?	10 0		
			Full?	10 2		
9	II.	Tr. I.	Ext. contact.	6 41 19	6 47	Stormy; cloudy.
18	II.	Oc. R.	First seen.	6 5 20	6 8	Hazy.

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	*N. Almanac* Time.	Remarks.
1894.				h m s	h m s	
Feb. 18	II.	Oc. R.	Ext. contact.	6 6 40		
	II.	Ec. D.	Fading.	6 22	6 25 19	Hazy.
			Just gone.	6 24 26		
	II.	Ec. R.	First seen.	8 41 17	8 41 27	Clear sky.
			Half out?	8 43 15		
			Full?	8 45 12		
24	I.	Ec. R.	First seen.	8 18 27	8 18 47	Wind and snow showers; some thin cloud.
Mar. 1	III.	Tr. E.	Ext. contact.	8 20	8 20	Stormy.
			Bisected.	8 16		
4	I.	Sh. E.	Int. contact.	7 24	7 26	Bad definition.
	II.	Oc. D.	Ext. contact.	9 0 17	9 3	Bad definition.
			Bisection.	9 2 10		
			Just gone.	9 4 32		

Notes.

(Instrument: The 9½-inch Cooke Refractor, power 240.)

January 14, 1893.—II. Tr. I. The satellite is as bright as the limb of *Jupiter*, perhaps a little brighter. It did not lose any of its apparent brightness as it approached the limb.

February 8.—II. Tr. E. The satellite was not visible till $7^h\ 10^m$; it was on a bright zone.

August 14.—Satellite I. was invisible at 13^h; it passed on to disc at $12^h\ 14^m$.

September 21.—III. Oc. D. The satellite passed behind the disc near the N. pole of *Jupiter*; seemed to skirt the limb; very difficult to observe the phases of the phenomenon.

October 8.—I. Tr. I. The satellite became invisible soon after it had passed on to the disc; it seemed much brighter than the adjacent bright surface of *Jupiter* just before its transit began.

December 9.—I. Tr. I. The satellite was invisible at $6^h\ 15^m$.

December 16.—I. Tr. I. It was invisible at 8^h and at $9^h\ 15^m$.

January 31, 1894.—I. was invisible at 8^h, so also at 9^h and $9^h\ 15^m$.

January 17.—I. in transit; not visible at 5^h, nor at $5^h\ 30^m$; on a grey belt close to a bright zone.

III. Tr. I. Very difficult to say when satellite is just in external contact; satellite not far from S. pole of planet. Similar case on October 16, 1893.

February 18.—II. Oc. R. The satellite when just past external contact looked very small in the dark sky.

Differences of R.A. and N.P.D. of Uranus and 8 Libræ and a Libræ about the time of the conjunction in 1894 April, observed with the Transit-circle at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Comparisons with 8 Libræ.

Day. 1894.	Observer.	♅−✱ R.A.	Assumed R.A. of ✱.	Apparent R.A. of ♅.	Secs. of Tab. R.A.	Error of Tab. R.A.	♅−✱ N.P.D.	Assumed N.P.D. of ✱.	Apparent N.P.D. of ♅.	Secs. of Tab. N.P.D.	Error of Tab. N.P.D.
		m s	h m s	h m s	s	s	′ ″	° ′ ″	° ′ ″	″	″
Apr. 18	B.	+1 35·10	14 44 51·27	14 46 26·37	26·74	+0·37	+4 50″70	105 33 38″92	105 38 29″62	30″5	+0″88
21	A. C.	+1 6·11	51·31	45 57·42	57·82	+0·40	+2 40·85	39·02	36 19·87	20·7	+0·83
27	C. D.	+0 7·03	51·38	44 58·41	58·74	+0·33	...	...	...	...	...
30	A. C.	−0 23·00	51·42	44 28·42	28·79	+0·37	−4 0·65	39·42	29 38·77	40·5	+1·73
				Comparisons with a Libræ.							
Apr. 18	B.	+1 23·67	14 45 2·71	14 46 26·38	26·74	+0·36	+2 8·65	105 36 19·90	105 38 28·55	30·5	+1·95
21	A. C.	+0 54·69	2·75	45 57·44	57·82	+0·38	+0 1·36	20·05	21·41	20·7	−0·71
30	A. C.	−0 34·49	2·86	44 28·37	28·79	+0·42	−6 41·30	20·50	39·20	40·5	+1·30

The assumed mean places of the stars for 1894·0 are as follows :—

8 Libræ	R.A. h m s 14 44 49·36	N.P.D. ° ′ ″ 105 33 23″42	Authority, Greenwich Ten Year Catalogue, 1880.
a „	„ 14 45 0·79	„ 105 36 4·50	„ „ Five Year Catalogue of Fundamental Stars, 1890.

In all cases the stars and planet were observed in the same position of the instrument.
The N.P.D differences have been corrected for refraction and parallax.
The tabular places for *Uranus* are those given in the *Nautical Almanac*.
The initials A. C., B., C. D. are those of Mr. Crommelin, Mr. Bryant, and Mr. Davidson, respectively.

Royal Observatory, Greenwich:
1894 *May* 9.

Observations of Gale's Comet (b 1894), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to one another, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time. 1894.	d	h	m	s	Observer.	⌀−✱ R.A. m	s	Corr. for Refraction. s	Log. factor of Parallax.	⌀−✱ N.P.D. °	′	″	Corr. for Refraction. ″	Log. factor of Parallax. ″	No. of Comps.	Apparent R.A. h	m	s	Apparent N.P.D. °	′	″	Comp. ✱
May	1	8	47	8	A. C.	−0	9·00	−0·02	9·4850	+	2	18·2	+0·6	0·8765	2	7	53	42·97	105	24	25·6	*a*
	1	8	52	58	B.	−0	5·62	−0·02	9·4926	+	1	14·0	+0·4	0·8748	4	7	53	46·35	105	23	21·2	*a*
	4	8	42	29	,,	−0	9·11	+0·01	9·4252	−	1	55·5	−0·1	0·8511	6		...			...		*b*
	7	9	4	32	,,	+0	5·93	+0·02	9·4338	−10	31	6	−0·2	0·8030	7	8	57	43·35	82	35	28·4	*c*
	7	9	24	52	,,	+0	44·47	−0·03	9·4661	+15	44	5	+0·4	0·8061	5	8	57	51·20	82	32	50·1	*d*
	9	10	8	45	C. D.	+0	57·99	0·00	9·5200	−	0	23·3	0·0	0·7845	8	9	15	0·53	76	37	23·7	*e*
	9	10	12	33	A. C.	+0	59·59	0·00	9·5240	−	0	48·1	−0·1	0·7856	1	9	15	2·13	76	36	58·8	*e*
	10	9	0	5	C. D.	−1	9·81	0·00	9·4170	+	1	24·6	+0·1	0·7428	4	9	22	23·88	74	11	17·8	*f*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

May 7.—Stellar nucleus seen south of centre of nebulosity; slight elongation of latter towards N.

The initials A. C., B., C. D., are those of Mr. Crommelin, Mr. Bryant, and Mr. Davidson, respectively.

Comparison Stars.

	Star's Name.	R.A. 1894·0. h	m	s	N.P.D. 1894·0. °	′	″	Authority.
a	O.A. (S.), 7742	7	53	51·72	105	22	1·5	Oeltz. Arg. (S.), and Schjellerup.
b	B.D.−3°, 2390	8	28	22·6	93	17	8	Bonn, Observations, Vol. viii.
c	W.B. VIII., 1423	8	57	36·58	82	45	59·7	Glasgow, 1870, Paris and Göttingen Catalogues.
d	W.B. VIII., 1414	8	57	5·94	82	17	4·9	Glasgow, 1870, Paris and Armagh, 1875, Catalogues.
e	W.B. IX., 235	9	14	1·58	76	37	48·1	Paris Catalogue.
f	W.B. (2) IX., 450	9	23	32·65	74	9	54·7	Weisse's Bessel (2).

Royal Observatory, Greenwich: 1894 *May* 11.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. JUNE 8, 1894. No. 8

Captain de W. ABNEY, R.E., C.B., D.C.L., F.R.S, President, in the Chair.

The Rev. John Thomas Windmill Claridge, B.A., 3 Albert Road, Tamworth, Staffordshire ;

David Goudie Simpson, 199 Camberwell Grove, Denmark Hill ;

The Rev. Ernest Harrison Smith, M.A., R.N., H.M.S. *Tourmaline*, North American and West Indian Station ; and

Sir John Benjamin Stone, The Grange, Erdington, near Birmingham,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

George Cox Bompas, 121 Westbourne Terrace, Hyde Park, W. (proposed by A. Cowper Ranyard) ;

Bryan Cookson, Magdalen College, Oxford (proposed by H. H. Turner) ; and

Lieut. Basil Taylor, R.N., H.M.S. *Blake*, North American Station (proposed by Sir Josiah Rees).

Eighty presents were announced as having been received since the last meeting, including amongst others :—

The Photochronograph (three papers), presented by Georgetown College Observatory ; Agnes Giberne, The Starry Skies,

presented by the author; Müller and Kempf, Photometrische Durchmusterung des nördlichen Himmels, Theil I. (Potsdam Observatory Publications, vol. ix.), presented by the Observatory; Pulkowa Observations, vol. x., Mesures micrométriques des étoiles doubles, presented by the Observatory; Series of enlargements of portions of the lunar surface from negatives taken at the Lick Observatory, presented by Dr. Weinek; Series of original negatives of *Jupiter*, presented by the Lick Observatory; two photographs of Gale's Comet, taken at Sydney Observatory, presented by H. C. Russell.

On the Dimensions of Saturn's Disc. By Hermann Struve.

An exact determination of a planet's diameter necessarily meets with great difficulties, especially of optical origin. On account of the imperfect union of the rays of light passing the object-glass, the boundaries of a planet's disc are surrounded by a bright secondary spectrum, and are not sharply defined. This defect of distinctness is still further increased by diffraction and by the unsteadiness of the atmosphere. Further, the dispersion of light in our atmosphere produces different coloration on the southern and on the northern boundary of the planet. The decrease of brightness of the disc from the centre to the borders, together with the atmosphere of the planet, will also contribute to deteriorate the distinctness of the boundaries. From consideration of all these troublesome causes it is evident that what we accept as boundary is open to a wide range, and that, from this reason, the accuracy of the measures will be greatly inferior to that which we are used to attain in the observation of fixed stars. This uncertainty sufficiently explains both the differences in the determinations of diameter obtained by different observers, and their dependence upon accidental circumstances—as, for instance, the quality of the images, the transparency of the air, the brightness and colour of the field, &c.

Experience has also proved that determinations of diameter depend in some degree upon the micrometer employed. Double-image micrometers have generally furnished smaller values than filar micrometers. The origin of this difference is not yet sufficiently explained. No doubt with the filar micrometer the setting of the dark wire on the bright limb of the planet might easily be subject to constant errors. On the other hand a similar error of estimation may exist in producing the contact of the two images by a heliometer. In any case, the observations with a powerful refractor, compared with those made by a heliometer of comparatively small dimensions, are certainly superior in this respect, that the image in the focus is considerably larger, and thus the same magnifying power can be reached with eyepieces of greater focal length.

To what extent our knowledge of the dimensions of planets is still imperfect is obvious if we compare the results obtained by different observers for the same discs. We will here content ourselves with a reproduction of some determinations concerning *Saturn* that might be compared hereafter with the results of my own observations. The diameters are here all reduced to the mean distance of the planet, 9·5389.

Observer.	Epoch.	Equat. diam. $2a$.	Polar diam. $2b$.	Axis of the Ring. $2d$.	
		″	″	″	
W. Struve	1826	17·99		40·10	fil. micr. 9-in. refr.
*Bessel	1829–33	17·06	15·39	39·33	Königsberg heliometer.
Encke	1837	17·68	16·49	40·94	fil. micr. 9-in. refr.
Galle	1838	17·91		40·91	fil. micr. 9-in. refr.
*Main	1848	17·50	15·60		Airy's micr. $6\frac{3}{4}$-in. refr.
O. Struve	1851	17·59		39·73	fil. micr. 15 in. refr.
Lassell	1852	17·45		40·88	jaw micr. (?) 20-f. reflector.
Jacob	1853	17·87	16·52	39·93	fil. micr. 6-in. refr.
*Main	1852–55	16·22		39·73	Airy's micr. $6\frac{3}{4}$-in. refr.
*Secchi	1854–56	17·66		40·89	fil. micr. 9-in. refr.
Jacob	1856	17·94		40·00	fil. micr. 6-in. refr.
Mædler	1860–63	17·18	15·85		fil. micr. 9-in. refr.
*Main	1862	16·88	15·11		Oxford heliometer.
*Kaiser	1856, 1862–63	17·27	15·39	39·72	Airy's micr. 7-in. refr.
*Kaiser	1865–66	16·83	15·47	39·47	Airy's micr. 7-in. refr.
*W. Meyer	1880	17·40	16·18	40·43	fil. micr. $10\frac{1}{4}$-in refr.
*W. Meyer	1881	17·77	16·12	40·35	fil. micr. $10\frac{3}{4}$-in. refr.
O. Struve	1882	17·76		40·16	fil. micr. 15-in. refr.
*A. Hall	1884–87	17·72		40·45	fil. micr. 26-in. refr.

The asterisks denote determinations deduced from observations made on ten or more nights. It will be seen that for all three diameters the differences amount to $1''$–$2''$; even if we reject some determinations as of inferior quality or as based on too small a number of measures, still there remains an uncertainty of at least half a second. In contrast with the results, $2a=17''{\cdot}1$, $2d=39''{\cdot}5$, deduced by Bessel and Kaiser from numerous careful observations made on the heliometric method, we have as the mean of the best observations made with filar micrometers $2a=17''{\cdot}7$, $2d=40''{\cdot}3$, and it cannot be decided *à priori* which of these results is less affected by systematic errors. Similar uncertainties exist for the diameters of the other planets. Even for *Jupiter*, offering more facility to the measures than all the other planets, the differences in the determinations by various observers are nearly as large. The discs of *Uranus* and *Neptune*, as seen by the most power-

ful instruments, are so indistinct that even the question of a sensible ellipticity of *Uranus* is still quite open. For *Mars* and *Venus* observers have tried, by measures made at different distances from the Earth, to determine and eliminate the constant errors of their measures; nevertheless, it remains undecided whether the errors of the measures do not depend on the apparent diameter and the brightness of the disc. A negative answer seems the more probable.

Only occasionally a small number of direct measures of *Saturn's* diameter has been made by me in the common manner by help of the filar micrometer applied to the 30-inch Pulkowa refractor. But the numerous observations of the satellites contain also several series of measures, which, though in an indirect way, lead to determinations of the diameter that may well be compared with direct measures. *Hyperion* has furnished six, *Rhea* two, and *Titan* also two series of measures, in which the satellite has been referred to different parts of the planet's limb. Of this number those obtained by *Hyperion* as intermediate object are, of course, less exact than those by the other satellites. For this reason I thought it advisable at first not to take them into account.

The junctions of *Rhea* with the disc of *Saturn*, in the years 1889 and 1890, were undertaken, in the first place, for the determination of the eccentricity of this satellite's orbit, which could not be deduced with certainty from the junctions with other satellites. *Rhea* was successively joined with the opposite borders of the planet's disc, both in equatorial and polar direction. The moderate opening of the ring in the years mentioned was particularly favourable for this mode of observing. By a convenient arrangement of the measures, consisting each of eight pointings both in equatorial and polar directions, the motion of the satellite in the intervals was so nearly eliminated that there remained only a very small correction to be applied to the diameter. In the same manner the junctions of *Titan* with the planet's disc were executed in the two following years, 1891 and 1892. A new determination of *Titan's* orbit appeared desirable, and the satisfactory result obtained for *Rhea*, together with a particular circumstance that shall be more fully explained below, determined me to maintain for *Titan* the same method of observation.

Concerning the accuracy of these measures, I may remark that the elements of the orbits of the satellites might be deduced from them almost with the same exactitude as from the junctions of the satellites with one another. The errors remaining after solution of the equations of condition lead to the probable error $=\pm 0''\cdot 065$ for a single observation. It is only for the last series, during which the position of the planet was less favourable, that it was found somewhat greater, viz., $=\pm 0''\cdot 095$. But as the determination of the planet's diameter was only a secondary object in these measures, and particular attention

had only to be directed to the most *uniform* pointing of the micrometric wire on the opposite borders of the planet, it could not be expected that the results for the diameter would be found quite so accordant as those for the co-ordinates of the satellite. In fact, on several occasions it has been noted in the journal that the wire had not been pointed exactly on the border of the planet, but equally inside or outside. It is also noted that in the later series the wires have been placed rather more outside than in the first series.

The following list exhibits the single results deduced for the diameters from the series of observations made on *Titan*, 1891. They are reduced to the mean distance of the planet, and the polar diameters have already received the necessary correction for the elevation of the Earth above the equator of *Saturn*. The greater part of these observations were made with illuminated reddish field and an achromatic eyepiece of power 515. At the end of this series the background was sufficiently bright to admit measures without artificial illumination of the field.

Series made in 1891.

	Diameter.		Ellipticity.	Image.
	$2a$	$2b$	$\frac{a-b}{a}$	
	"	"		
1891 Mar. 2	17·66	15·49	0·123	3-2
11	17·27	15·63	0·095	4
13	17·48	15·74	0·100	3-4
14	17·42	16·04	0·079	4-3
18	17·39	15·72	0·096	4-3
20	18·04	15·90	0·119	3
23	17·74	16·00	0·098	2-3
24	18·01	15·84	0·120	3
25	17·44	15·49	0·112	3-4
26	17·31	15·78	0·088	4
27	17·27	15·56	0·099	3-4
Apr. 1	17·26	15·21	0·119	4
4	17·67	15·78	0·107	3
6	17·47	15·78	0·097	4-3
9	17·48	15·72	0·101	4
11	17·39	15·68	0·098	3
13	17·39	15·97	0·082	3
14	17·55	15·85	0·097	3-4
15	17·61	15·99	0·092	3-4
20	17·80	15·69	0·119	2
21	17·55	16·12	0·081	3
22	17·60	15·92	0·095	2-3
24	17·87	15·68	0·123	3-2
27	17·63	15·99	0·093	3
30	17·91	15·90	0·112	3
May 1	17·84	16·28	0·088	3-4
Mean ...	17·579	15·798	0·1013 ± 0·0018	

In the last column the quality of the images is indicated by the numbers 1–5, the last number representing the best quality. If we divide the measures into two sections according to the quality of the images—better or worse than 3—we get the following mean values :—

For images	>3	$2a = 17''.445$	$2b = 15''.753$	13 obs.
,,	$\leqq 3$	$= 17''.712$	$= 15''.843$	13 obs.

Hence it will be seen that in this series, with better images, both diameters have been found somewhat smaller. The same relation holds throughout all the other series.

The *final* results deduced from the four above-mentioned series of observations are as follows :—

		$2a$	$2b$	$\frac{a-b}{a}$	
By the series for	Rhea 1889	$17''.230$	$15''.333$	0.1100 ± 0.0018	19 obs.
,, ,,	,, 1890	$17''.352$	$15''.650$	0.0981 ± 0.0019	23 ,,
,, ,,	Titan 1891	$17''.579$	$15''.798$	0.1013 ± 0.0018	26 ,,
,, ,,	,, 1892	$17''.722$	$15''.758$	0.1108 ± 0.0021	25 ,,
Mean	... ...	$17''.471$	$15''.635$	0.1050	by 93 obs.

The smaller values of the first series are in part explained by the remark made above ; those of the last series may have been found somewhat too great—in part on account of the inferior quality of the images ; in part, perhaps, owing to the circumstance that with the increased narrowness of the ring the extremities of the equatorial diameter were not quite free. However, I confess I did not expect such large differences in the perception of the boundaries as are indicated by the values found in the different series, for all the observations have been made by one and the same observer, with the same instrument and in the same manner. We can only refer to the foregoing remarks in order to throw some light on such discrepancies.

On this occasion another circumstance might be mentioned, to which the preceding observations have directed the attention, and which seems to be of some importance for our judgment on the determinations obtained by direct measures. In my investigation of the orbit of *Rhea* from the first series of observations I came to the conclusion that the co-ordinates, measured in the polar direction, required a constant negative correction of about $0''.2$ to represent the whole series in a satisfactory manner. If this correction had had its origin in the existence of a sensible eccentricity of the orbit it would have almost disappeared in the observations of the following year, when the aperture of the orbit had considerably diminished. But also in the next year the correction amounted to almost the same value. Likewise the co-ordinates of *Titan*, observed in the years 1891 and 1892,

required corrections in the same sense, and even to a somewhat larger amount. By the introduction of such a constant correction in the equations of condition their solution gives for it the following values :—

Rhea	1889	$dy = -0''.16$	$\pm 0''.022$
„	1890	$= -0''.13$	$\pm 0''.017$
Titan	1891	$= -0''.18$	$\pm 0''.015$
„	1892	$= -0''.20$	$\pm 0''.020$

This result cannot be well explained otherwise than by supposing that the optical centre of the planet, as deduced from measures in polar direction, does not coincide with the centre of gravity of the system, but is situated somewhat to the south.

We must, therefore, conclude that the pointings of the wire have been executed in a different manner on the north and on the south border of the planet, and it is very natural to suppose that in great part these differences are to be attributed to the different coloration of the two poles, produced by the dispersion of the rays of light in our atmosphere. This different coloration has been noted on several occasions as troublesome for the pointings. While the south pole presented commonly a sharply defined boundary, surrounded by a small reddish border, distinctly projected on the secondary spectrum of the planet, the north pole appeared rather indistinct in bluish light.

It might be presumed at first that commonly the observer will accept as the south boundary of the planet's disc the arc formed by the red rays of the spectrum, while in a fixed star or a satellite only the brightest part of the spectrum comes into consideration. If we designate by Δz the refraction at the zenith distance z for rays of mean refrangibility n_0, its variation for rays of the index n can be expressed by the formula

$$\delta\Delta z = \frac{n - n_0}{n_0 - 1}\,\Delta z.$$

Accepting n_0 as corresponding to the D line, we have, according to Mascart's researches on the dispersion in the atmosphere,

For the C line	$\frac{n-n_0}{n_0-1}$	$= -0.00335$
„ E „		$= +0.00431$
„ F „		$= +0.00811$

Thus, for the difference of refraction of yellow and red rays—

$$\delta\Delta z = -0.00335 \,.\, \Delta z = -0''.19 \tan z;$$

or for $z = 50°$, the mean zenith distance of the planet at this time—

$$\delta\Delta z = -0''.23.$$

As the brightest parts of the spectrum, which also are best united in the focus, are situated between D and E, we might conclude that the difference between the brightest and the red rays would be somewhat greater still. Therefore, to explain the observed deviation of the optical centre to the south, it would be sufficient to admit a displacement of the south border alone. But it might be admitted quite as well that not only the south boundary but also the north boundary had suffered a similar displacement --in reference to the stars of comparison—and it is evident that for this reason the determinations of the polar diameter and of the ellipticity are subject to considerable uncertainties.

It might, perhaps, be decided by measures executed at greater horary angles on both sides of the meridian which of the two borders of the planet is more displaced to the south, for similar differences would then be found for the co-ordinates in the equatorial direction. My observations are not qualified for this purpose, as they have been all made at comparatively small distances from the meridian. It would be also of some interest to examine whether similar displacements exist in the measures of other observers. If they exist, they must be considered not only in the determination of diameters, but also in other problems, as, for instance, in the deduction of the solar parallax from observations of *Mars*, &c.

Another method for the determination of the dimensions of a planet presents itself in the observation of eclipses of satellites. This method is not subject to the troubles existing in the direct measures, but it requires, on the other hand, an exact knowledge of the orbits of the satellites. My observations on the system of *Saturn*, continued for several years, with the 30-inch refractor, have determined the elements of the orbits of the satellites within such narrow limits that it appears justifiable to try what the eclipses of satellites and the transits of *Titan*, occasionally observed in the years 1890–1892, will give for the dimensions of the planet's disc. The interesting results obtained in this way form the principal object of the present communication.

We possess but a very small number of eclipses of *Saturn's* satellites observed in former periods. Thus W. Herschel, during his long series of observations on *Saturn* in 1789, only once observed a reappearance of *Titan*, which observation has been thoroughly discussed by Bessel in his memoir on the orbit of this satellite. Captain Jacob mentions (*Monthly Notices*, xiii. page 240) that in 1853 he had observed a disappearance of *Tethys*. Further, in the report on the observations of Lassell and Marth in Malta, we find one single reappearance of *Tethys* recorded in 1863. Perhaps other records of similar phenomena may yet be found in different papers; but since astronomers formerly could not avail themselves of predictions of these phenomena, as we possess them at present

in the excellent ephemerides of Mr. Marth, such observations could only be made accidentally. It is hardly necessary to remark that these observations can only be obtained with accuracy if the phenomenon happens at a sufficient distance from the limb of planet and ring. For this reason they can be made only in comparatively short periods, and require for the nearer and smaller satellites powerful instruments and favourable images; while, on the other hand, with the more distant larger satellites these phenomena occur less frequently. These conditions will also partly explain why recent years, in which these phenomena could be observed, have furnished only a poor harvest. Besides six observations obtained by me in 1890 and 1891, I have knowledge of only four observations made at Princeton by Professor Young, and of two at Sittingbourne by Mr. Freeman. I believe, however, that with the favourable conditions of 1891 I might have succeeded in observing more eclipses if only my attention had been particularly directed to them. But I was afraid that thereby the principal object of my observations would have suffered, and must confess that, in fact, I was impressed with the exactness and the importance of these observations only when it was too late to make up for lost opportunities.

In the following account of observations made recently, all epochs are expressed in Greenwich mean time. The first Pulkowa observation does not refer to a real eclipse, but it is important as an extraordinarily near approach of *Dione* to the border of the shadow. Professor Young's observations, published in the *Astronom. Journal*, No. 248, and those of Mr. Freeman in the *Memoirs of the Brit. Astr. Association*, vol. ii., are reproduced here verbatim.

Observations made at Pulkowa (with the 30-inch refractor).

1890 *April* 28. *Near Approach of Dione to the Shadow.*

Dione was attentively looked for from $9^h\ 26^m$ to $10^h\ 22^m$ (G.M.T.). All this time it remained nearly quite as bright as *Tethys*, and appeared only for moments somewhat less bright. A complete eclipse certainly did not take place. The observed small changes in the brightness can be sufficiently explained by the variability of the images 2–4.

1890 *May* 20. *Eclipse of Dione. Disappearance and Reappearance.*

$7^h\ 18^m$ (G.M.T.). *Dione* passed the southern conjunction with the planet about 10^m or 15^m ago. It appears rather small on account of the still bright sky, but can be well seen. Images variable 2–4.

$7^h\ 21^m\ 41^s$. *Dione* nearly as bright as *Tethys*.

$7^h\ 25^m\ 17^s$. *Dione* becomes more feeble.

$7^h\ 26^m\ 32^s$. *Dione* certainly diminishing; difficult to see.

$7^h\ 28^m\ 32^s$. *Dione* not more visible. Beginning from $7^h\ 26^m\ 32^s$ it could not be seen with certainty.

$7^h\ 49^m\ 28^s$. *Dione* still eclipsed.

$7^h\ 50^m\ 28^s$. While *Enceladus* now easily visible, there is no trace of *Dione*.

$7^h\ 56^m\ 47^s$. *Dione* still invisible.

$8^h\ 8^m\ 25^s$. *Dione* begins to reappear; first glimpse a little earlier.

$8^h\ 9^m\ 42^s$. *Dione* grows brighter.

$8^h\ 10^m\ 35^s$. *Dione* easily visible; almost of the same brightness as *Tethys*.

$8^h\ 14^m\ 24^s$. *Dione* nearly in conjunction with the eastern limb of the planet, not yet quite up. It can be seen without difficulty, much more easily than *Enceladus*.

Assumed: $7^h\ 26^m{\cdot}7$ and $8^h\ 7^m{\cdot}4$ as moments of total eclipse.

1891 *April* 11. *Reappearance of Tethys.*

$9^h\ 14^m$. *Tethys* invisible.

$9^h\ 15^m\ 34^s$. *Tethys* begins to reappear from the shadow; first trace remarked about 5^s before the indicated time. Its light grows rapidly.

$9^h\ 15^m\ 40^s$. *Tethys* already quite bright. The distance from the limb of the planet is about $2''$–$3''$. This observation is very accurate, the images being very good (4). The duration of the reappearance, counted from the moment of first remarked trace to that of full brightness, can hardly exceed 15^s.

1891 *April* 13. *Reappearance of Tethys.*

$6^h\ 12^m$ to $6^h\ 33^m$. Attentively looked for *Tethys*, but not recognised. Images 3-4.

$6^h\ 34^m$. *Tethys* not yet discernible.

$6^h\ 34^m\ 42^s$. *Tethys* feeble.

$6^h\ 35^m\ 6^s$. *Tethys* considerably brighter and easily seen.

$6^h\ 35^m\ 29^s$. *Tethys* in full brightness.

I believe that I remarked the first trace of reappearance at $6^h\ 34^m\ 38^s$.

1891 *April* 30. *Reappearance of Tethys.*

$6^h\ 21^m\ 19^s$. *Tethys* not visible.

$6^h\ 27^m\ 13^s$. *Tethys* appearing, perhaps first remarked 10^s–15^s earlier. Images 3.

$6^h\ 27^m\ 20^s$. No doubt full brightness.

About three minutes before the reappearance of *Tethys* was noted the images were very poor; also at that time the sky was still rather bright. However, I do not believe that these circumstances have occasioned a sensible retardation of the reappearance.

1891 *April* 30. *Reappearance of Dione.*

$7^h\ 17^m$ to $7^h\ 40^m$. No trace of *Dione*. Images very variable.

$7^h\ 40^m\ 26^s$. *Dione* still invisible.

$7^h\ 41^m\ 14^s$. *Dione* reappears. Image 3. I believe the moment is certain within 5^s.

$7^h\ 41^m\ 22^s$. *Dione* somewhat less bright than *Tethys*.

$7^h\ 41^m\ 58^s$. *Dione* almost of the same brightness as *Tethys*. The reappearance of *Dione* happened approximately at half-way between *Tethys* and the planet's limb.

This reappearance was also observed by Mr. Renz with the 15-inch refractor. He notes $7^h\ 42^m\ 13^s$ as the moment when *Dione* was certainly recognised as having reappeared, but remarks that the images had been very variable, and sometimes so poor that neither *Dione* nor even *Tethys* could be recognised.

Observations made at Princeton, U.S. (23-inch refractor).

1891 *April* 8. *Reappearance of Rhea.* Halsted Observatory. Professor Young Obs.

Satellite reappeared at $13^h\ 56^m{\cdot}0 \pm 30^s$. (G.M.T.) The phenomenon had not been looked for, but was observed unexpectedly, and the time is a little uncertain.

1891 *April* 17. *Reappearance of Rhea.* Halsted Observatory. Professor Young Obs.

Satellite first glimpsed at ...	$14^h\ 53^m\ 45^s$
Bright as *Enceladus*	$14^h\ 54^m\ 50^s \pm 5^s$
Bright as *Tethys*	$14^h\ 56^m\ 20^s \pm 10^s$
Full brightness before ...	$14^h\ 57^m\ 30^s$

1891 *April* 26. *Reappearance of Rhea.* Halsted Observatory. Professor Taylor Reed Obs.

First seen	$15^h\ 52^m\ 4^s$
Bright as *Enceladus*	$15^h\ 53^m\ 24^s \pm 5^s$
Bright as *Dione*	$15^h\ 54^m\ 19^s \pm 15^s$
Bright as *Tethys*	$15^h\ 54^m\ 34^s \pm 15^s$
Full brightness	$15^h\ 57^m\ 0^s \pm 1^m$

Same phenomenon observed at the School of Science Observatory by Professor Young, with $9\frac{1}{2}$-inch telescope.

First seen	$15^h\ 53^m\ 2^s$
Bright as *Tethys*	$15^h\ 54^m\ 37^s \pm 5^s$

1891 *April* 27. *Reappearance of Dione.* Halsted Observatory. Professor Young Obs.

Satellite first seen at $13^h\ 58^m\ 30^s$; full light regained in about 1^m. Same observed at School of Science Observatory by Professor T. Reed, satellite first seen at $13^h\ 58^m\ 30^s$ (exactly the same as observed by Young with the 23-inch; probably Young's observation was late).

Observations made at Sittingbourne.

(By Rev. A. Freeman. $6\frac{1}{2}$-inch refractor.)

1892 *January* 4. *Disappearance of Rhea.*

$14^h\ 0^m$. (G.M.T.) *Rhea* was well seen.
$14^h\ 5^m$. *Rhea* shining less brightly.
$14^h\ 5^m\ 37^s$. *Rhea* gone.

1892 *January* 31. *Disappearance of Titan.*

At $16^h\ 52^m\ 35^s$ *Titan* was seen.
At $17^h\ 1^m\ 50^s$ *Titan* was not seen.

Concerning the situation of the equator on the planet's disc, the discussion of the observations requires only approximate values. We will accept

$$n = 167^\circ\ 58'.7 \qquad i = 28^\circ\ 4'.3$$

with regard to the ecliptic.

We will likewise refer to the ecliptic the elements of the orbits of the satellites, and count them from the true equinox. Thus for the years in which the reported observations have been made we will accept, as deduced from my observations, the following values for mean longitude, node, and inclination :

Tethys, 1891.

April 0·0 rod. G.M.T.

$$\left.\begin{array}{rl} E = & 175^\circ\ 45'.0 \\ n = & 168\ \ 54.8 \\ i = & 27\ \ 6.7 \end{array}\right\} 1891\ .\ 232$$

Dione, 1890.	*Dione*, 1891.
April 0·0.	April 0·0.
$E = 24^\circ\ 8'.9$	$E = 154^\circ\ 25'.7$
$n = 168\ 1.7$	$n = 168\ 8.0$
$i = 28\ 9.4$	$i = 28\ 8.6$

Rhea 1891.	*Rhea* 1892.
April 0·0.	April 0·0.
$E = 212^\circ\ 8'.5$	$E = 218^\circ\ 41'.6$
$n = 167\ 36.1$	$n = 167\ 27.7$
$i = 28\ 22.4$ } 1891 . 232	$i = 28\ 21.6$ } 1892 . 290

Further, it must be considered that the yearly indirect motion of the node on the equator of *Saturn* is for *Tethys* 72°·5, for *Rhea* 10°·2. The plane of *Dione's* orbit coincides so nearly with

the equator of *Saturn* that only the perturbations caused by the other satellites produce some small deviations from the mean orbit, which in this case are of no consequence.

For *Tethys* no sensible eccentricity could be deduced with certainty from my observations; whereas for *Dione* and *Rhea* the eccentricity though small is certain, viz.—

For Dione.	*For Rhea.*
$e = 0{\cdot}00250$	$e = 0{\cdot}00090$
$P = 190° + 30° (t - 1890 \cdot 2)$	$P = 315° + 10° (t - 1890 \cdot 2)$

The mean motions of the satellites in the period that we have to consider here may be taken as follows:

Tethys, daily motion	190°·69770
Dione „ „	131·53495
Rhea „ „	79·69010

and the semi-axes at the mean distance 9·5389

Tethys	42″·583
Dione	54·540
Rhea	76·170

which values will approximately correspond to the mass of *Saturn* $\frac{1}{3500}$.

For *Titan* the micrometrical junctions with the planet have furnished the following elements of its orbit:

	Titan 1891. April 0·0.	*Titan* 1892. April 0·0.
E	92° 59′·36	76° 10′·12
n	168 19·40	168 17·92
i	27 40·46	27 40·44
P	276 49	278 0
e	0·02857	0·02876

we have further:

The mean daily motion	22°·577013
The semi-axis of the orbit	176″·600

The elements for 1891 being more accurately deduced than those for 1892, we have preferred to use the former in the following computations, except with regard to e, the greater value of which, as found in 1892, agrees better with the older observations.

With the given data the heliocentric co-ordinates of the

satellite referred to the planet's centre can be deduced in equatorial and polar direction. Therewith, by the formula

$$u^2 + \frac{v^2}{1 - e_0^2 \cos^2 B} = a^2 = \frac{b^2}{1 - e_0^2}$$

the equatorial or polar semidiameter of *Saturn's* spheroid will be determined when the elevation of the Sun above the planet's equator B and the value of

$$e_0^2 = \frac{a^2 - b^2}{a^2}$$

are approximately known. As in all such observations the elevation of the Sun must be very small, the quantities a or b can be deduced nearly independently of e_0, according as the passage arrives near the central line or near the boundary of the shadow.

The latter condition has happened with the observations of 1890. On April 28 *Dione* was not eclipsed, but it passed so near the boundary of the shadow that thereby immediately a maximum value can be deduced for b. By the elements of the orbit we find that the heliocentric conjunction had taken place at $8^h\ 50^m$ red. G.M.T., and for this moment the distance of the satellite from the centre of the planet referred to the mean distance:

$$v = -8''{\cdot}033.$$

Accepting, then, with Bessel approximately

$$\frac{a - b}{a} = 0{\cdot}0980,$$

we find for the polar semidiameter

$$b < 8''{\cdot}013.$$

On May 20 an eclipse of *Dione* took place which lasted about forty minutes. From this duration we can deduce the polar semidiameter almost independently of the eccentricity and the longitude of the satellite. However, for control we will give the values of b as they result separately from disappearance and reappearance. Here we will first consider only the observed times of complete eclipse.

Referring the values always to the mean distance of the planet, we get then:

For the disappearance	$6^h\ 9^m{\cdot}8$	red. G.M.T.	$u = -1''{\cdot}518$	$v = -7''{\cdot}718$
„ reappearance	$6\ 50{\cdot}5$	„	$= +2{\cdot}028$	$= -7{\cdot}709$

and thus the polar semidiameter:

From the disappearance $b = 7''{\cdot}821$

„ „ reappearance $= 7{\cdot}906$

If the moments were altered by a whole minute the effect on the evaluated b would be only $db = 0''\cdot015$; further, if we express dn and di in arcs, the unit being 1′, we find

$$db = +0''\cdot0071 \,.\, dn + 0''\cdot0031 \,.\, di.$$

As the adopted values of n and i may be estimated for *Dione* as exact within 3′ and 1′·5, the uncertainty arising in the determination of b from this cause can amount only to about $0''\cdot03$.

In the same manner the observations of 1891 can lead to a determination of the equatorial semidiameter almost independent of the ellipticity. Confining, again, our deduction at first to the moments of total eclipse, the reappearances observed at Pulkowa and Princeton give the following results, to which we subjoin the change of a by a minute of time in the observed moments :

		Red. G.M.T. h	m	u	v	a	da
						$''$	$''$
Pulkowa, 1891 April	11	8	4·23	Te.	+8·162	−2·713	8·698	0·090
„ „	13	5	23·21	Te.	+8·172	−2·698	8·702	0·090
„ „	30	5	13·81	Te.	+8·238	−2·547	8·708	0·091
„ „	30	6	27·94	Di.	+8·252	−2·683	8·771	0·081
Princeton, „	8	12	45·0	Rh.	+7·569	−3·876	8·703	0·063
„ „	17	13	41·91	Rh.	+7·673	−3·688	8·694	0·064
„ „	26	14	39·25	Rh.	+7·808	−3·498	8·718	0·065
„ „	27	12	45·38	Di.	+8·211	−2·723	8·748	0·080

or in the mean :

By the Pulkowa observations	$a = 8''\cdot720$
„ Princeton „	$= 8\cdot716$

The agreement of the results derived from the observations of three different satellites is striking and can hardly be desired better. Not only is the high value of this kind of observation thereby sufficiently proved, but at the same time a most reliable control is furnished for the elements of the orbits in use. In fact, if, for instance, we had not taken into account the small deviations of the orbit-planes from the equator of *Saturn*, or the eccentricities of the orbits of *Dione* and *Rhea*, the deduced values of a would have presented very considerable differences. We cannot but regret that in the same year no disappearances were observed before opposition, which would have materially added to the weight of evidence.

The two eclipses observed by Rev. A. Freeman in 1892, treated in the same manner, give :

		Red. G.M.T. h	m	u	v	a	da
						$''$	$''$
Disapp. Rhea 1892 Jan.	4	12	49·58	−8·419	+1·699	8·627	0·070
„ Titan „	31	15	49·05	−7·032	+3·917	8·264	0·039

The first value of a is in tolerable agreement with the foregoing determinations. But the result derived from the eclipse of *Titan* deviates too much for the difference to be explained by admissible errors of the elements or by the semidiameter of the satellite. As Mr. Freeman used an instrument of only $6\frac{1}{2}$-inch aperture, it might be presumed that the disappearance happened for him rather early; but in that case the semidiameter of the planet should appear too great. Therefore, as in the report on these observations it is said only that at $16^h\ 52^m\ 35^s$ *Titan* was still visible, and that at $17^h\ 1^m\ 50^s$ it could no longer be seen, I am inclined to suppose that the last-mentioned moment does not exactly correspond with the real disappearance, which perhaps had happened a few minutes before. On this supposition the deduced value would only represent an inferior limit.

The values of a and b, as deduced above from the moments of first or last remarked glimpse of the satellites, require some small positive corrections, depending in part on the diameters of the satellites, in part on the effect of the half-shadow. Though at present we must content ourselves with general estimations, the observations at our disposal offer already some interesting indications in this respect. My observations of 1891 show that *Tethys*, in its central passage, only occupied 50^s at the most from the first glimpse to the full brightness. The observations of April 11 and April 30 would even indicate a considerably shorter duration for the increase of light. For *Dione* my observations make the duration $=44^s$, and Professor Young says "about one minute," which values would also approximately agree with the fact that on 1890 May 20 *Dione* on passing through the extreme boundary of the shadow required about 3–4 minutes to recover full brightness. Concerning *Rhea* we may assume, according to the Princeton observations, that in its central passage the increase of light lasted at least 3–4 minutes.

Accepting, then, for the increase of light 40^s for *Tethys* and $3\frac{1}{2}^m$ for *Rhea*, these values would correspond to a motion of the satellite of respectively $0''.06$ and $0''.22$. These quantities may be regarded as equal to the diameters of the satellites, augmented by the effect of the half-shadow, which for *Tethys* may be estimated at $0''.042$, for *Rhea* $0''.074$. But the reappearance of the satellite will be noticed only when already part of its limb is outside of the central shadow, and on the other hand full brightness will commonly be observed too early, when a small part of the satellite is still in the shadow. Admitting that these circumstances may reduce the correction for half-shadow to its half, we should have for the diameter of *Tethys* the value $0''.04$, for *Rhea* $0''.18$. On the other hand it is worthy of attention that for *Tethys* and *Dione*, two satellites of approximately the same brightness, the masses have been found to be almost equal (cf. *Astron. Nachr.*, 2984), while *Rhea* is not quite twice as bright, and its mass

hardly six times greater. Hence it appears less probable that the diameter of *Rhea* is more than double that of *Tethys*. Moreover, a diameter of 0″·18 would probably be discerned in powerful instruments. Perhaps this contradiction, with the increase of light observed on *Rhea*, might find an explanation in the atmosphere of the planet, which, partly by absorption partly by refraction, must increase the half-shadow, and thereby also the duration of the phenomenon, particularly for the more distant satellites.

So far as I can judge now, I am inclined to suppose that in my observations the duration of the whole phenomenon has been estimated too short, in those of Princeton somewhat too long. Accepting as a mean value for *Tethys* and *Dione* the duration $=1^m$, for *Rhea* $=2\frac{1}{2}^m$, the diameters of the satellites would result respectively 0″·07 and 0″·12. Accordingly we might further admit that the interval between the first glimpse of the satellite and its appearance in the central line of the half-shadow has lasted $0^m\cdot3$ with *Tethys* and *Dione*, $1^m\cdot0$ with *Rhea*. Thereby the diameters of the planet, as above deduced, would have to be increased by 0″·027 for *Tethys*, by 0″·024 for *Dione*, and by 0″·064 for *Rhea*. Thus we get the following list of determinations:

1891	Apr.	11	Reapp.	Te.	$a = 8''\cdot725$	Pulkowa
	,,	13	,,	Te.	8·729	,,
	,,	30	,,	Te.	8·735	,,
	,,	30	,,	Di.	8·795	,,
1891	,,	8	,,	Rh.	8·767	Princeton
	,,	17	,,	Rh.	8·758	,,
	,,	26	,,	Rh.	8·782	,,
	,,	27	,,	Di.	8·772	,,
1892	Jan.	4	Disapp.	Rh.	8·691	Sittingbourne
1890	May	20	Disapp.	Di.	$b = 7''\cdot845$	Pulkowa
	,,	20	Reapp.	Di.	7·930	,,

or in the mean of all

the equatorial diameter of the planet $2a = 17''\cdot500$

,, polar ,, ,, $2b = 15\cdot775$

the ellipticity $\frac{a-b}{a} = 0\cdot0986$

This value of the ellipticity of the ball agrees perfectly with Bessel's determination, while each of the diameters had been observed by him too small by 0″·4. From the comparison with my own direct measures, it must further be concluded that the

above-mentioned displacement of the optical centre of the disc to the south applies equally, and perhaps even more, to the north as to the south border of the planet.

The above results, which show that the dimensions of *Saturn* must be taken as somewhat greater than Bessel had found them, are also confirmed by some observations of transits of *Titan* over the planet's disc made in 1892. In my journal the moments of the two egresses of the satellite, observed April 12 and April 28, are noted, and on the first day also ingress and egress of its shadow; on the second day the transit of the shadow close to the southern border of the disc.

Egress of Titan. 1892 *April* 12.

$9^h\ 6^m{\cdot}4$ (G.M.T.). First impression that *Titan* on emerging appeared as a protuberance on the limb of the planet. Image 3.

$9^h\ 12^m{\cdot}4$. *Titan* certainly recognised as emerging.

$9^h\ 15^m{\cdot}4$. *Titan* distinctly prominent, but not yet separated from the limb. Some time before *Titan* had been already observed as a dark spot on the disc of the planet. On approaching to the limb, the dark spot became fainter, and finally, shortly before the egress, I lost it entirely from view.

Egress of Titan. 1892 *April* 28.

$7^h\ 1^m{\cdot}4$. The small dark disc of *Titan* pretty well visible, cutting out a segment on the limb of the planet. Images 4–3.

$7^h\ 10^m{\cdot}6$. The segment on the limb can still be distinctly recognised.

$7^h\ 18^m{\cdot}4$. The emerging satellite appears as a protuberance on the limb.

$7^h\ 21^m{\cdot}9$. The satellite completely emerged, but apparently still in contact with the limb.

Between the disappearance of the segment and the first appearance of the satellite as a protuberance, five minutes can hardly have elapsed. This night *Titan*, passing over a brighter band of the planet's disc, appeared considerably darker than on April 12, presenting itself as a brownish spot of about $0''{\cdot}5$ diameter.

Ingress and Egress of Titan's Shadow. 1892 *April* 12.

$7^h\ 44^m{\cdot}8$. Ingress of the shadow, perhaps remarked already a few minutes before.

$7^h\ 49^m{\cdot}8$. The shadow completely immersed.

$10^h\ 8^m{\cdot}4$. On emerging the shadow appears as a segment on the limb of the planet.

$10^h\ 11^m{\cdot}4$. The shadow can still be recognised.

The transit of the shadow over the central line of the

planet was observed at $8^h\ 52^m \pm 2^m$. At this time the centre of the shadow appeared about 1″ distant from the southern border of the planet. A micrometric junction of the shadow with the southern border was therefore not practicable.

Shadow of Titan on the Planet's Disc. 1892 *April* 28.

The beginning and end of this phenomenon could not be well observed on account of clouds. I first saw the shadow at about $7^h\ 52^m$, when it formed already a considerable segment on the limb. The transit over the central line was noted at $8^h\ 10^m$, and thirty minutes later I could still well recognise the shadow as a segment on the south-western border. On passing though the central line the superior border of the shadow appeared almost in contact with the planet's limb.

The details of the observations show that for the observed moments of ingress and egress we must admit rather larger limits of uncertainty. Therefore it will be sufficient to prove that these observations agree satisfactorily with the results above deduced. Accepting for egress of the centre of the satellite the moments, April 12 $9^h\ 12^m{\cdot}6$, and April 28 $7^h\ 14^m{\cdot}8$, we derive from the elements of its orbit the geocentric co-ordinates of the satellite, and hence the equatorial semidiameter of the planet (referred to the mean distance), as follows:

1892 Apr. 12	$u = -8''{\cdot}23$	$v = -2''{\cdot}35$	$a = 8''{\cdot}64$
„ 28	$= -8{\cdot}66$	$= -1{\cdot}21$	$= 8{\cdot}77$

From the description of the observations we are inclined to believe that the determination of April 28 is the more exact.

The ingress and egress of the shadow present a similar control for the polar semidiameter. Accepting the first observed moment, $7^h\ 44^m{\cdot}8$, as corresponding to the ingress of the centre of the shadow, and the last moment, $10^h\ 11^m{\cdot}4$, to its egress, we find for them the following heliocentric co-ordinates:

for ingress	$u = +3''{\cdot}57$	$v = -7''{\cdot}15$
for egress	$= -3{\cdot}55$	$= -7{\cdot}12$

As the ingress had happened on the phase side, the egress on the illuminated side of the planet, for the latter the geocentric projection must be taken into account. For this reason the value of the semidiameter, as deduced from the heliocentric place of the egress by means of the formula given above, must be somewhat increased by the amount of the phase that would exist in the indicated place if Earth and Sun had exchanged rôles. But in this case the phase is so small that we do not

commit a sensible error if we substitute the preceding values without correction. Thus we get for the polar semidiameter—

$$\text{by the ingress } b = 7''\cdot84$$
$$\text{by the egress } = 7\cdot81$$

The transit of the shadow observed 1892 April 28 is particularly interesting. The elements of the orbit give for the heliocentric distance of the two centres at the time of conjunction the value

$$v = -7''\cdot87 + 0''\cdot023 \,.\, dn - 0''\cdot009 \,.\, di,$$

in which dn and di denote admissible errors of the elements expressed in minutes of arc. As dn must be estimated $< 2'$, and $di < 1'$, we conclude that the value $v = -7''\cdot87$ will be exact within $0''\cdot06$. If then the centre of the planet's shadow, as the observations have proved, has projected itself at the time of conjunction on the planet's disc, b must certainly be greater than $7''\cdot81$. This value must even be increased by approximately $0''\cdot2$ to account for the remark that at the time of conjunction the entire shadow had been seen on the disc. But perhaps that remark is in part due to an optical deception; or it might also be supposed that a part of the shadow became visible by projection on the outer atmosphere of the planet, and by effect of refraction it entered in the lower strata. Whatever might be the origin of the phenomenon, Bessel's dimensions of the planet can hardly be reconciled with it. On the contrary, it indicates that even the results found by the eclipses for the polar diameter are rather too small.

The exact knowledge of the orbits of the satellites furnishes also the means of deducing the dimensions of the ring from observed conjunctions of its ansæ with the satellites. This method appears particularly favourable for the years when the aperture of the ring is small. From my own observations in 1892—viz. 4 conjunctions of *Enceladus*, 3 of *Tethys*, 2 of *Dione*, and 2 of *Rhea*—I deduce by this way for the axis of the ring the mean value

$$2d = 39''\cdot2;$$

agreeing well with the mean of Bessel's measures, and considerably smaller than all the other determinations. A difference in the extent of the ansæ east and west is not discernible. But a systematic difference seems to exist in so far that the more distant satellites *Rhea* and *Dione* have furnished somewhat smaller values than the nearer satellites *Tethys* and *Enceladus*. It would be worth while to extend this research to the numerous conjunctions observed in other places.

Pulkova: 1894 *April*.

Note on the Lunar Theory. By Professor Ernest W. Brown, M.A.

I have determined the following coefficients in longitude depending on the eccentricity of the Sun. The notation used is Delaunay's. The coefficients are the parts of the form $e' f(m)$, and are accurate to the last place of decimals given.

$$\begin{aligned} V = \ldots &- 659''\cdot2375 \sin l' + 152''\cdot0828 \sin (2D - l') - 21''\cdot5942 \sin (2D + l') \\ &+ 1''\cdot2550 \sin (4D - l') - 0''\cdot1800 \sin (4D + l') \\ &+ 0''\cdot0105 \sin (6D - l') - 0''\cdot0015 \sin (6D + l') \\ &+ 0''\cdot0001 \sin (8D - l'). \end{aligned}$$

These agree well with Delaunay's values when estimate is made for the omitted portions of the series in powers of m, the greatest difference being $0''\cdot06$.

I hope shortly to publish the coefficients of the form $ee' f(m)$, which are amongst the least accurate of all Delaunay's coefficients owing to the slow convergence of the series in powers of m.

Haverford College:
1894 *May* 3.

On some Points connected with the Integration of the Differential Equations of the Relative Motions of Material Systems. By E. J. Stone, M.A., F.R.S., Radcliffe Observer, Oxford.

In problems of the relative motions of material points subject to their mutual gravitational attractions, when the masses are denoted by

$$1 : \nu_1 : \nu_2 : \ldots \nu_p,$$

and the corresponding coordinates, referred to the unit-mass as origin, by

$$\xi_1, \eta_1, \zeta_1 ; \xi_2, \eta_2, \zeta_2 ; \text{ \&c.},$$

the three differential equations for the motion of each mass assume the well-known forms—

$$(1) \quad \ldots \ldots \quad \begin{aligned} \frac{d^2\xi_1}{dt^2} &= -f(1+\nu_1)\frac{\xi_1}{\rho_1^3} + \int f \cdot \nu \cdot \frac{d\mathrm{R}}{d\xi_1} \\ \frac{d^2\eta_1}{dt^2} &= -f(1+\nu_1)\frac{\eta_1}{\rho_1^3} + \int f \cdot \nu \cdot \frac{d\mathrm{R}}{d\eta_1} \\ \frac{d^2\zeta_1}{dt^2} &= -f(1+\nu_1)\frac{\zeta_1}{\rho_1^3} + \int f \cdot \nu \cdot \frac{d\mathrm{R}}{d\zeta_1} \\ &\text{\&c.} = \text{\&c.} \end{aligned}$$

where $\rho_1^2 = \xi_1^2 + \eta_1^2 + \zeta_1^2$; and f denotes the accelerating effect of the unit-mass at the unit-distance in the unit-time.

The symbol $\int$ denotes summation extending over all the material points of the system. If any of the masses are so small that their accelerating effects are insensible, the corresponding symbols ν may be neglected in the summation; but if included in the mathematical work, numerical values, sensibly zero, will be found for them from a discussion of the observations when accuracy has been secured.

If found convenient the relative motions of any two material points about the unit-mass may be resolved, in the mathematical treatment, into that of the motion of their common centre of gravity about the unit-mass, and their motion about the common centre of gravity; and any other *exact* algebraical transformations of the equations may be introduced and used without modification of the general principles upon which the solution of such physical problems depend.

The $3p$ differential equations for the motion of such a system contain $(p + 1)$ constants $f, \nu_1, \nu_2 \ldots \nu_p$; and their general integrals, if determinable, will contain, in addition to these, the $6p$ constants which are required to give the necessary generality to the results, so that they may include all the possible cases of the relative motions of such a system of material points. If the adopted units of length and of time are independent of the particular system of relative motions under discussion, the whole of the $(7p + 1)$ constants will have to be found from observations of that system, and their determination will be *sufficient* for the complete solution of the physical problem. But if the times are found from the relative motions themselves, the determination of the "time" from observation will replace the determination of the two constants, to which definite values are assigned in the equations to render the variable t determinate.

If we express the coordinates under the forms

$$\xi = x + \delta x, \eta = y + \delta y, \zeta = z + \delta z,$$

and thus introduce six functions to express the position of each mass relatively to the unit-mass, we shall require for each mass, besides the three differential equations of motion, three additional equations, differential or otherwise, to render the coordinates

$$x + \delta x, y + \delta y, z + \delta z$$

determinate. When additional functions, such as $\check{\imath}x$, $\check{\imath}y$, $\check{\imath}z$, are introduced, the functions x, y, z may be called primary functions, and the functions $\check{\imath}x$, $\check{\imath}y$, $\check{\imath}z$, auxiliary functions. When the primary functions x, y, z are known, the auxiliary functions will be determinable from the differential equations.

$$(2) \ldots \frac{d^2\delta x}{dt^2} = -f(1+\nu)\frac{x+\delta x}{\rho^3} - \frac{d^2x}{dt^2} + \int f.\nu.\frac{d\mathrm{R}}{d(x+\delta x)}$$

&c. = &c.

But as no loss of generality necessarily results from the introduction of these auxiliary functions, the general integrals found by adding them to the primary functions will include the relative motions of any system of $(p+1)$ material points however distributed, and moving at a particular instant; and from the equal generality of the results, the real difficulties of the general integration of the equations (2) with selected primary functions will not be less than those which would be experienced in the integration of the original differential equations of motion. But if we have found *in any way* values of the functions x_1, y_1, z_1, x_2, y_2, z_2, &c., which represent approximately the motions in some particular case of mass distribution and motion with which we are concerned; and we can, therefore, *rightly* assume that in this particular case the ratios

$$\frac{\delta x}{r}, \quad \frac{\delta y}{r}, \quad \frac{\delta z}{r},$$

where

$$r = \sqrt{x^2 + y^2 + z^2}$$

are always small fractions; we can, in finding the auxiliary functions required for the complete integration of the differential equations of motion for the particular system with which we are concerned, restrict our investigations to those cases in which the ratios

$$\frac{\delta x}{r}, \quad \frac{\delta y}{r}, \quad \frac{\delta z}{r}$$

are small fractions; and the integration of the differential equations (2) can then be effected by successive approximations in which different orders of the fractions

$$\frac{\delta x}{r}, \quad \frac{\delta y}{r}, \quad \frac{\delta z}{r}$$

are neglected in succession.

We shall not obtain by following this method the general integrals for the relative motions of any system of $(p+1)$ material points, but those for the special system with which we are practically concerned.

If the primary functions x, y, z adopted for any moving mass, ν, are definite functions of t, and contain no arbitrary constants to be found from observation, the six arbitrary constants required to give the necessary generality to the results must be introduced in the integration of the differential equations (2); and in this case the general integrals of the auxiliary functions δx, δy, δz will have to be found.

But if the necessary constants have been introduced in the primary functions x, y, z, it will only be necessary to find particular integrals of the differential equations (2), and the work will be greatly facilitated in those cases in which the ratios

$$\frac{\delta x}{r}, \quad \frac{\delta y}{r}, \quad \frac{\delta z}{r}$$

are small fractions; but in approximating to the expressions for these particular integrals it will be impossible to assign to the arbitrary constants contained in the functions x, y, z approximate numerical values, unless the errors which arise from the use of these approximate values are at every stage of the mathematical work of the order of the neglected terms

$$\frac{\delta x}{r}, \quad \frac{\delta y}{r}, \quad \frac{\delta z}{r}.$$

If we adopt, as is usual in the problems of gravitational astronomy, the complete integrals of the differential equations

$$(3) \quad \frac{d^2x}{dt^2} = -f(1+\nu) \cdot \frac{x}{r^3}; \qquad \frac{d^2y}{dt^2} = -f(1+\nu) \cdot \frac{y}{r^3}; \qquad \frac{d^2z}{dt^2} = -f(1+\nu) \cdot \frac{z}{r^3}$$

for the primary functions, we can express x, y, z under the forms

$$x = r[\cos v \cdot \cos \Omega - \sin v \cdot \sin \Omega \cdot \cos \gamma]$$

$$y = r[\cos v \cdot \sin \Omega + \sin v \cdot \cos \Omega \cdot \cos \gamma]$$

$$z = r \cdot \sin v \cdot \sin \gamma$$

$$r = a(1 - e \cos \phi) \; ; \; \tan \frac{v-\omega}{2} = \sqrt{\frac{1+e}{1-e}} \cdot \tan \phi$$

$$\phi - e \sin \phi = \sqrt{\frac{f(1+\nu)}{a^3}} \cdot (t+\tau)$$

where a, e, ω, τ, Ω, γ are six constants introduced in the integrations.

But the primary functions x, y, z thus obtained are not the integrals of the differential equations of motion unless the accelerating effects of the masses ν_1, ν_2, ν_3, . . . ν_p are insensible, and this is not the case in the problems with which we have to deal in astronomy. It will not, therefore, be possible to obtain with sensible accuracy the numerical values of the constants contained in the differential equations of motion and their integrals by equating the functions x, y, z with the coordinates of the moving masses as found from observation. If this is attempted, and definite values are assigned to x, y, z in the formation of the differential equations (2), the general integrals, instead of the partial integrals, of these equations will be required to ensure accuracy. If, however, we accept the primary elliptic integrals for the functions x, y, z, and use them, *in their general form*, in the formation of the differential equations

$$(4) \quad \frac{d^2\delta x}{dt^2} = -f(1+\nu)\left[\frac{x+\delta r}{\rho^3} - \frac{x}{r^3}\right] + \int f \cdot \nu \cdot \frac{d\mathrm{R}}{d(x+\xi)}$$

$$\&c. = \&c.$$

the *partial* integrals δx, δy, δz found from these equations, free from any additional arbitrary constants, will by their addition to the primary functions x, y, z give solutions of the differential equations of motion. But the integration of the equations (4) will not lead to the required integrals of the differential equations of motion unless the functions x, y, z which are *actually used for the formation of the differential equations* (2) *are integrals of the primary differential equations* (3). This point is of more practical importance than may at first sight appear to be the case, and it is liable to be overlooked in carrying out the laborious operations required for the determination of the auxiliary functions δx, δy, δz for the different masses. The same units of length and of time will have to be adopted in the formation of the differential equations of motion for all the material points whose relative motions are under discussion; or, what practically comes to the same thing, if different units are employed the ratios of the different units must be accurately known, and allowed for in the formation of the differential equations. But when the same units of length and of time are adopted, the numerical value of the factor f, which appears in each of the primary functions, will require that the same numerical value should be assigned to it in all the primary functions and retained throughout the investigations of the auxiliary functions δx, δy, δz. When, therefore, angular velocities

$$n_1, n_2, n_3 \ldots n_p$$

are introduced to replace the complex functions

$$\sqrt{\frac{f(1+\nu_1)}{a_1^3}}, \quad \sqrt{\frac{f(1+\nu_2)}{a_2^3}}, \quad \sqrt{\frac{f(1+\nu_p)}{a_p^3}},$$

the primary differential equations will not be satisfied unless we have *identically for each material point*

$$(5) \quad \ldots\ldots \quad f=\frac{a_1^3 n_1^2}{1+\nu_1}; \quad f=\frac{a_2^3 n_2^2}{1+\nu_2}; \quad f=\frac{a_p^3 n_p^2}{1+\nu_p};$$

and, in order that the units of length and of time may be the same throughout our mathematical investigations of the motion of the system, the same numerical value must be assigned to f in all the primary integrals, and we must have, therefore, the following identities:

$$(6) \quad \ldots\ldots\ldots \quad \frac{a_1^3 n_1^2}{1+\nu_1}=\frac{a_2^3 n_2^2}{1+\nu_2}=\frac{a_p^3 n_p^2}{1+\nu_p}.$$

In the equations (6) a_1, a_2, ... and n_1, n_2, ... denote constants introduced in the integrations which have to be found from observations of the relative motions of the particular system under discussion, but they are not independent of each other. Indeed, if it were possible to overlook the conditional relations (6), instead of the $(7p+1)$ constants which are *sufficient* for the

complete solution of the physical problem under consideration, we should have placed at our disposal $8p$ constants determinable from observation.

These remarks are equally true when the method of the variation of parameters is employed. If a', n' denote two variable parameters subject to the condition

$$(7) \quad \ldots\ldots\ldots \quad f = \frac{n'^2 a'^3}{1+\nu},$$

we shall have

$$(8) \quad \ldots\ldots\ldots \quad 2a'^3 n' \cdot \frac{dn'}{dt} + 3n'^2 a'^2 \cdot \frac{da'}{dt} = 0,$$

or,

$$\frac{dn'}{dt} = -\frac{3}{2}\frac{n'}{a'} \cdot \frac{da'}{dt}$$

as a *necessary*, but not a *sufficient* conditional relationship between the parameters a', n' for the solution of the physical problem under discussion. It will also be necessary for the solution of the problem of relative motions of the $(p+1)$ material points that the constants introduced in the integration of the differential equations from which a' and n' are found should be such that they give the same numerical value for f when substituted in the equation (7) for all the masses, ν_1, ν_2, &c.; and it is only by showing that this condition is satisfied that the truth of Newton's law of universal gravitation can, strictly speaking, be established.

The angular velocities

$$n_1 \cdot n_2 \ldots \text{ \&c.}$$

and the linear quantities

$$a_1 \cdot a_2 \ldots \text{ \&c.}$$

can, therefore, only be accurately found from observation subject to the conditions imposed by the identities (6), and the introduction of redundant constants into the theoretical expressions must be carefully avoided.

But if the expressions for the coordinates

$$x + \delta x,\ y + \delta y,\ z + \delta z,$$

which are compared with the results of observation, are *sensibly incomplete, or affected with sensibly erroneous empirical corrections*; and values of the angular velocities n_1, n_2, &c., and of the linear constants a_1, a_2, &c., or of their equivalents

$$\left(\frac{f(1+\nu_1)}{n_1^2}\right)^{\frac{1}{3}},\ \left(\frac{f(1+\nu_2)}{n_2^2}\right)^{\frac{1}{3}},\ \text{\&c.},$$

are thus obtained from a discussion of a limited series of residual discordances by the method of least squares or otherwise, there is no mathematical necessity whatever, if Newton's law of gravitation is true, that the equations of condition (6) should be satisfied by the values of the constants thus found ; or any proof that the physical problem has been solved by the process followed, unless it can be shown that the values of f, found from the discussion of the residual discordances, in connection with the constants n_1, n_2, &c., ν_1, ν_2, &c., are sensibly the same for all the material points.

But in the problems of the relative heliocentric motions of the centres of gravity of the planets, the motions under mathematical treatment are not directly dependent upon the rotation of the Earth about its axis, or on the linear dimensions of the Earth ; and it is possible in the discussions of these relative motions to clear the fundamental constant f from fallible errors of determination, and to render its value *absolutely definite throughout our mathematical investigations by the selection of suitable units of length and of time.* But when this course is followed, the angular velocity of the Earth about its axis and the linear dimensions of the Earth referred to the units selected to render f definite will have to be found from a discussion of observations, and the values which will be found from these discussions will necessarily be liable to fallible errors of determination.

The difficulties thus presented are inherent in the physical problem under consideration, and they cannot be avoided by any mathematical artifices of change of constants or of variables. The close agreement between the values recently obtained for the constant of solar parallax from discussions of such very different geocentric motions as those of the Moon, Venus, Mars, and the asteroids, values which may be said to be confined within such limits as 8″·80 and 8″·90, is sufficient to prove that the outstanding errors of our geocentric coordinates are confined within small limits. But the exact values of the solar parallax cannot be obtained with certainty from such discussions, however accurately the geocentric distances of a planet from neighbouring stars or from the Sun are measured at any particular time, until the ratios of the linear constants

$$a_1, a_2, \text{ &c.,}$$

as well as the values of such constants as

$$e_1, e_2, \text{ &c.,}$$

are accurately known. I should be inclined to believe that the progress of gravitational astronomy is at present retarded from incompleteness of our theoretical investigations, the employment of inconsistent conditions between the variable t and

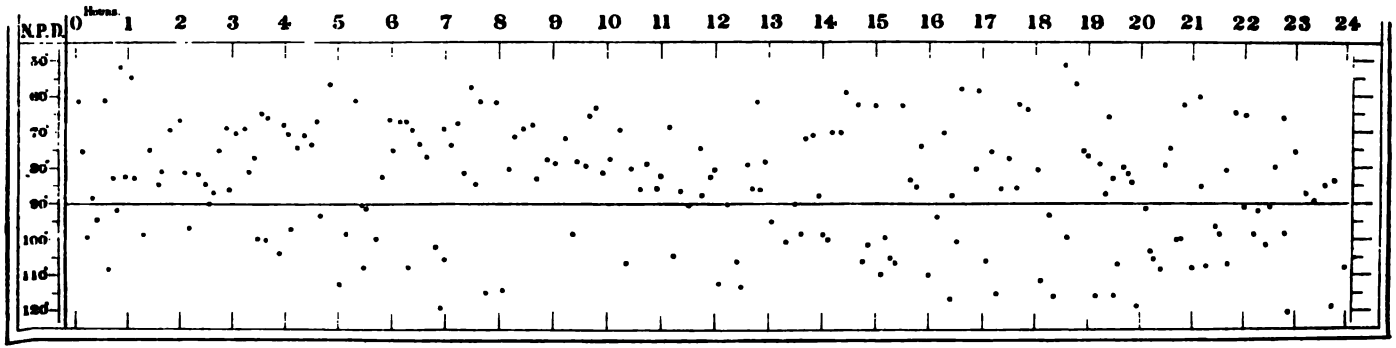
facts of observation, and the introduction of redundant constants to diminish the residual errors formed from observations extending over only limited intervals of time, rather than from existing errors of observation. But such errors are undoubtedly quite sensible, and every step which tends to diminish them is one in the right direction, and should be most carefully utilised.

Note on the Distribution of the Stars generally used for the Determination of Clock-Error. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The authorities at Greenwich for a great many years have annually published and distributed a list of the Mean Right Ascensions of some 215 stars, brought up from the latest *Greenwich Catalogue*, and corrected, when necessary, from recent observations. This list has been found exceedingly useful by many astronomers, more particularly for the determination of the errors of their clocks. The apparent places of most of the Greenwich stars are included in the current *Nautical Almanacs*; and I understand that the whole of them will be included in future volumes. But the *distribution* of the clock-stars in this list about the equator is not very satisfactory, and I have thought that this might easily be improved; and, to test opinion on this point, the following list has been prepared. I have not ventured to cut out any of the stars which are now on the Greenwich list; but if the number of stars required to fill up the gaps should be thought to render the total number of stars inconveniently large for that constant re-observation which is desirable, there are some of the stars now in the list which might be cut out without any serious practical loss. The Right Ascensions given for the additional stars are close approximations to the true values; and although they are not at present as accurate as the Right Ascensions of most of the other stars, the errors are so small that, if adopted for clock-stars, their places would be rapidly improved without leading to any practical inconvenience.

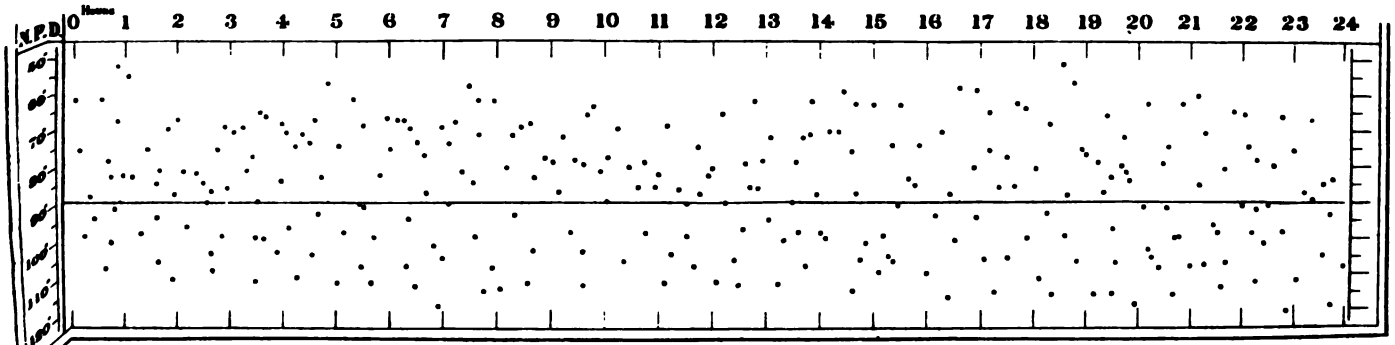
Two diagrams showing the general distribution of the stars are appended.

Stars in the Greenwich Clock-Star List between 50° & 120° N.P.D.



Stars in the Greenwich Clock-Star List between 50° & 120° N.P.D.

with proposed additional stars.



Greenwich List of Clock-Stars, 1894.

Name of Star.	Magnitude.	Mean R.A. 1894. h m s	Approx. N.P.D. ° ′
α Andromedæ	2	0 2 54·44	61 30
γ Pegasi	3–2	0 7 46·58	75 24
ι Ceti	3–4	0 14 1·56	99 25
44 Piscium	6	0 19 58·08	88 39
12 Ceti	6	0 24 37·70	94 33
ε Andromedæ	4	0 32 57·17	61 16
β Ceti	2	0 38 16·11	108 34
δ Piscium	5–4	0 43 10·89	83 0
20 Ceti	5	0 47 35·37	91 43
μ Andromedæ	4	0 50 52·02	52 5
ε Piscium	4	0 57 26·43	82 41
β Andromedæ	2–3	1 3 47·74	54 56
ζ¹ Piscium	5	1 8 11·48	82 59
θ Ceti	3	1 18 43·44	98 44
η Piscium	4–3	1 25 48·58	75 12
ν Piscium	4–5	1 35 54·81	85 3
ο Piscium	4	1 39 47·66	81 23
β Arietis	3–2	1 48 46·96	69 43
α Arietis	2	2 1 11·79	67 2
ξ¹ Ceti	5	2 7 22·79	81 39
67 Ceti	6–5	2 11 41·72	96 55
ξ² Ceti	4	2 22 31·30	82 1
ν Ceti	5–4	2 30 18·61	84 52
δ Ceti	4–3	2 34 2·89	90 8
γ Ceti	3	2 37 48·40	87 13
σ Arietis	6–5	2 45 38·32	75 21
ε Arietis	4–5	2 53 8·95	69 5
α Ceti	2–3	2 56 44·24	86 20
δ Arietis	4–5	3 5 33·95	70 40
τ¹ Arietis	5	3 15 6·34	69 14
ο Tauri	4–3	3 19 6·44	81 21
f Tauri	4	3 25 1·16	77 26
ε Eridani	4–3	3 27 56·11	99 49
11 Tauri	6	3 34 26·36	65 1
δ Eridani	3–4	3 38 10·15	100 7
η Tauri	3	3 41 10·93	66 13

Name of Star.	Magnitude.	Mean R.A. 1894. h m s	Approx. N.P.D. ° ′
γ^1 Eridani	3	3 53 4·96	103 49
A^1 Tauri	5–4	3 58 25·64	68 12
ω^1 Tauri	5–6	4 2 59·35	70 40
o^1 Eridani	4–5	4 6 41·41	97 7
γ Tauri	4	4 13 45·56	74 38
ϵ Tauri	4–3	4 22 25·55	71 3
Aldebaran	1	4 29 50·22	73 42
τ Tauri	4–5	4 35 52·90	67 15
μ Eridani	4–5	4 40 12·08	93 27
ι Aurigæ	3	4 50 5·37	57 0
ϵ Leporis	3–2	5 0 58·39	112 31
Rigel	1	5 9 26·58	98 19
β Tauri	2	5 19 35·43	61 29
δ Orionis	3–2	5 26 35·38	90 23
α Leporis	3–2	5 28 3·26	107 54
ϵ Orionis	2–1	5 30 50·05	91 16
α Columbæ	2	5 35 48·68	124 8
κ Orionis	2–3	5 42 43·71	99 42
α Orionis	1–2	5 49 25·95	82 37
1 Geminorum	5–4	5 57 40·56	66 44
ν Orionis	4–5	6 1 31·13	75 13
η Geminorum	3–4	6 8 28·72	67 28
μ Geminorum	3	6 16 32·82	67 26
β Canis Majoris	2	6 18 1·85	107 54
ν Geminorum	5	6 22 40·13	69 43
γ Geminorum	2–3	6 31 35·26	73 31
ξ Geminorum	3–4	6 39 20·36	76 59
θ Canis Majoris	4–5	6 49 15·85	101 54
ϵ Canis Majoris	2	6 54 27·54	118 50
ζ Geminorum	4	6 57 49·28	69 16
γ Canis Majoris	4–5	6 58 57·70	105 29
51 Geminorum	6–5	7 7 17·04	73 40
δ Geminorum	3–4	7 13 47·52	67 49
β Canis Minoris	3	7 21 24·11	81 30
Castor	2	7 27 50·20	57 53
Procyon	1	7 33 45·27	84 30
Pollux	1–2	7 38 49·79	61 43
ξ Argûs	3–2	7 44 50·12	114 36

Name of Star.	Magnitude.	Mean R.A. 1894.	Approx. N.P.D.
		h m s	° ′
6 Cancri	5	7 57 0·47	61 54
ρ Argûs	3–2	8 3 1·73	114 0
β Cancri	4–3	8 10 45·97	80 29
d^1 Cancri	6–5	8 17 17·64	71 20
η Cancri	6–5	8 26 34·74	69 12
γ Cancri	4–5	8 37 9·11	68 9
ε Hydræ	4–3	8 41 9·69	83 12
α Cancri	4	8 52 41·40	77 44
κ Cancri	6–5	9 2 0·36	78 54
83 Cancri	6	9 13 3·90	71 51
α Hydræ	2	9 22 22·67	98 12
ξ Leonis	5	9 26 13·91	78 14
ο Leonis	4–3	9 35 29·57	79 38
ε Leonis	3	9 39 50·07	65 44
μ Leonis	4	9 46 44·10	63 30
π Leonis	5	9 54 36·69	81 27
Regulus	1–2	10 2 43·60	77 31
γ^1 Leonis	3	10 14 7·71	69 37
μ Hydræ	4	10 20 57·77	106 18
ρ Leonis	4	10 27 13·78	80 9
34 Sextantis	6–7	10 37 9·05	85 52
l Leonis	5	10 43 41·12	78 54
d Leonis	5	10 55 5·15	85 49
χ Leonis	5	10 59 32·92	82 5
δ Leonis	2–3	11 8 28·28	68 54
δ Crateris	4–3	11 14 2·40	104 12
τ Leonis	5–4	11 22 29·13	86 34
υ Leonis	4–5	11 31 31·23	90 14
β Leonis	2	11 43 39·16	74 50
β Virginis	4–3	11 45 10·39	87 38
π Virginis	4–5	11 55 26·44	82 48
ο Virginis	4	11 59 48·55	80 41
ε Corvi	4–3	12 4 40·32	112 2
η Virginis	4–3	12 14 28·90	90 5
δ^2 Corvi	3–4	12 24 22·72	105 56
β Corvi	3–2	12 28 49·07	112 49
ρ Virginis	5–4	12 36 31·13	79 11
35 Virginis	6–7	12 42 27·53	85 51

Name of Star.	Magnitude.	Mean R.A. 1894. h m s	Approx. N.P.D. ° ′
31 Comæ	5–6	12 46 32·12	61 53
8 Virginis	3–4	12 50 15·80	86 2
ε Virginis	2–3	12 56 54·00	78 28
θ Virginis	4–5	13 4 27·62	94 58
Spica	2–1	13 19 36·46	100 36
ζ Virginis	4–3	13 29 17·44	90 3
88 Virginis	6–5	13 36 2·82	98 10
τ Boötis	5–4	13 42 13·46	72 1
η Boötis	3	13 49 38·23	71 4
τ Virginis	4–5	13 56 15·05	87 57
94 Virginis	7–6	14 0 40·90	98 23
κ Virginis	4–5	14 7 14·39	99 47
Arcturus	1	14 10 49·56	70 16
f Boötis	5	14 21 31·51	70 18
ρ Boötis	3–4	14 27 15·68	59 10
ϵ^2 Boötis	3	14 40 21·43	62 29
α Libræ	3	14 45 0·79	105 36
ξ^2 Libræ	5–6	14 51 0·92	100 59
ψ Boötis	4–5	14 59 54·21	62 38
ι^1 Libræ	5	15 6 10·66	109 23
β Libræ	3	15 11 18·08	98 59
σ^2 Libræ	7–6	15 17 6·96	104 45
ζ^1 Libræ	6–5	15 22 16·63	106 21
α Coronæ	2	15 30 11·95	62 56
α Serpentis	3–2	15 39 2·77	83 14
ε Serpentis	4–3	15 45 31·87	85 12
γ Serpentis	4–3	15 51 33·39	74 0
β^1 Scorpii	3–2	15 59 16·26	109 31
δ Ophiuchi	3–2	16 8 47·34	93 25
γ Herculis	3	16 17 14·58	70 36
Antares	1–2	16 22 54·40	116 12
λ Ophiuchi	3–4	16 25 33·97	87 47
ζ Ophiuchi	3–2	16 31 19·25	100 21
ζ Herculis	3–2	16 37 17·37	58 12
κ Ophiuchi	3–2	16 52 39·00	80 28
ε Herculis	3–4	16 56 13·98	58 55
η Ophiuchi	2–3	17 4 17·84	105 36
α^1 Herculis	3	17 9 48·80	75 29

Name of Star.	Magnitude.	Mean R.A. 1894. h m s	Approx. N.P.D. ° ′
θ Ophiuchi	4–3	17 15 29·89	114 54
σ Ophiuchi	5–4	17 21 15·26	85 46
α Ophiuchi	2–3	17 30 0·79	77 22
β Ophiuchi	3–2	17 38 14·11	85 23
μ Herculis	3–4	17 42 18·55	62 13
89 Herculis	6–5	17 51 8·58	63 56
72 Ophiuchi	3–4	18 2 19·42	80 27
μ Sagittarii	5–4	18 7 25·40	111 5
η Serpentis	3–4	18 15 49·42	92 56
λ Sagittarii	3	18 21 25·67	115 29
α Lyræ	1	18 33 20·94	51 19
2 Aquilæ	5–4	18 36 28·13	99 9
β^1 Lyræ	4–3	18 46 9·96	56 46
ϵ Aquilæ	4	18 54 48·65	75 5
ζ Aquilæ	3	19 0 32·25	76 18
ψ Sagittarii	5–6	19 9 2·42	115 26
ω Aquilæ	5	19 12 50·42	78 36
δ Aquilæ	3–4	19 20 9·20	87 6
α Vulpeculæ	5–4	19 24 17·65	65 33
μ Aquilæ	5–4	19 28 54·64	82 51
λ^2 Sagittarii	5–4	19 30 15·40	115 7
ϵ^1 Sagittarii	6–5	19 34 38·99	106 32
γ Aquilæ	3–2	19 41 13·17	79 39
α Aquilæ	1	19 45 36·65	81 25
β Aquilæ	4	19 50 6·33	83 51
c Sagittarii	5–4	19 56 8·37	118 0
θ Aquilæ	3–4	20 5 50·09	91 8
α^2 Capricorni	4–3	20 12 10·39	102 52
β Capricorni	3–4	20 15 3·31	105 7
ρ Capricorni	5	20 22 48·87	108 10
ϵ Delphini	4	20 28 8·89	79 3
α Delphini	4	20 34 42·83	74 28
ϵ Aquarii	4–3	20 41 56·25	99 53
μ Aquarii	5–4	20 46 56·16	99 23
32 Vulpeculæ	5	20 50 2·51	62 21
θ Capricorni	4–5	20 59 59·31	107 39
ζ Cygni	3–4	21 8 25·47	60 12
α Equulei	4	21 10 31·48	85 11

Name of Star.	Magnitude.	Mean R.A. 1894. h m s	Approx. N.P.D. ° ′
ι Capricorni	4–5	21 16 20·65	107 17
β Aquarii	3	21 25 58·70	96 2
ξ Aquarii	5–4	21 32 6·52	98 20
ε Pegasi	2–3	21 38 58·73	80 37
δ Capricorni	3	21 41 11·38	106 36
16 Pegasi	5	21 48 14·27	64 34
α Aquarii	3–4	22 0 20·32	90 50
ι Pegasi	4	22 2 4·53	65 10
θ Aquarii	4–5	22 11 14·38	98 19
γ Aquarii	4	22 16 10·83	91 55
σ Aquarii	5–4	22 25 2·24	101 13
η Aquarii	4–5	22 29 54·50	90 40
ζ Pegasi	4–3	22 36 10·47	79 43
μ Pegasi	4–3	22 44 53·17	65 57
λ Aquarii	4–3	22 47 5·03	98 9
Fomalhaut	1–2	22 51 47·57	120 11
α Pegasi	3–2	22 59 28·79	75 22
γ Piscium	4–3	23 11 40·16	87 18
κ Piscium	5	23 21 29·87	89 19
ι Piscium	4–5	23 34 29·81	84 57
δ Sculptoris	5–4	23 43 24·31	118 43
ω Piscium	4–5	23 53 52·02	83 43
2 Ceti	5–4	23 58 18·57	107 56

Proposed Additions to Clock-Star List.

Name of Star.	Magnitude.	Mean R.A. 1894. h m s	Approx. N.P.D. ° ′
58 Piscium	6–5	0 41 29·65	78 36
ϕ^2 Ceti	6–5	0 44 49·04	101 13
η Andromedæ	5–4	0 51 32·74	67 9
Lalande 3159	5–6	1 37 21·86	94 13
τ Ceti	4–3	1 39 8·54	106 30
υ Ceti	4	1 55 0·56	111 36
α Piscium	4	1 56 33·32	87 45
π Ceti	5–4	2 39 4·57	104 18
τ^1 Eridani	5–4	2 40 9·24	109 1
η Eridani	3–4	2 51 14·89	99 19
τ^6 Eridani	4	3 29 6·24	111 59
10 Tauri	5	3 31 27·78	89 56

Name of Star.	Magnitude.	Mean R.A. 1894. h m s	Approx. N.P.D. ° ′
ν Tauri	4	3 57 30·97	84 18
Lalande 8205	6–5	4 16 1·49	110 54
53 Eridani	4–5	4 33 19·45	104 31
π^1 Orionis	3–4	4 44 5·04	83 13
15 Orionis	5–4	5 3 37·84	74 32
ζ Tauri	3–4	5 31 18·56	68 55
γ Leporis	4	5 40 2·61	112 29
10 Monocerotis	5–6	6 22 43·51	94 42
ξ^1 Canis Majoris	4	6 27 26·24	113 21
18 Monocerotis	5–4	6 42 20·02	87 28
22 Monocerotis	5	7 6 27·05	90 19
γ Monocerotis	5–4	7 36 10·86	99 18
g Geminorum	5	7 39 59·27	71 14
B.A.C. 2666	5–6	7 55 6·94	108 6
Bradley 1197	4	8 20 21·79	93 34
Lalande 17103	6–5	8 34 29·40	112 18
12 Hydræ	5–4	8 41 22·00	103 9
θ Hydræ	4–3	9 8 50·98	87 14
κ Hydræ	6–5	9 35 13·46	103 51
Lalande 19034	5–6	9 36 26·75	113 6
15 Sextantis	5	10 2 30·69	89 51
41 Sextantis	6	10 44 58·97	98 20
β Crateris	5–4	11 6 26·62	112 15
θ Crateris	4–5	11 31 18·24	99 13
ζ Crateris	5–6	11 39 23·37	107 45
7 Comæ	5–6	12 10 58·73	65 28
χ Virginis	5	12 33 46·45	97 25
α Comæ	4–5	13 4 49·85	71 55
γ Hydræ	3	13 13 9·39	112 37
B.A.C. 4559	6–5	13 34 21·00	78 43
89 Virginis	6–5	13 44 6·64	107 36
9 Boötis	5	13 51 43·76	61 59
ζ Boötis*	3–4	14 36 5·19	75 49
4 Libræ	6–5	14 37 5·83	114 33
109 Virginis	4–3	14 40 53·34	87 40
τ^1 Serpentis	5–6	15 20 52·31	74 12

* The star, Piazzi XIV.–145, 6–7 mag., $14^h\ 35^m\ 38^s{\cdot}16$, 76° 1′, might be substituted for ζ Boötis, which is double.

Name of Star.	Magnitude.	Mean R.A. 1894.	Approx. N.P.D.
		h m s	° ′
11 Serpentis	6	15 27 30·27	90 50
30 Ophiuchi	6	16 55 28·17	94 4
δ Herculis	3-4	17 10 40 64	65 2
ξ Serpentis	4	17 31 30·97	105 20
ν Ophiuchi	4-3	17 53 11·40	99 46
109 Herculis	4	18 19 10·83	68 17
4 Aquilæ	5	18 39 28·91	88 3
O. A. (S.) 18841	6-5	18 49 37 84	106 30
κ Aquilæ	5-6	19 31 11·32	97 16
δ Sagittæ	4-3	19 42 39·66	71 44
23 Vulpeculæ	5-4	20 11 22·54	62 31
71 Aquilæ	4-5	20 32 51·81	91 28
ψ Capricorni	4-5	20 39 49·06	115 39
1 Pegasi	4-5	21 17 11·03	70 39
41 Capricorni	5-6	21 35 58·51	113 44
B.A.C. 7742	6	22 6 44·18	74 29
47 Aquarii	5-6	22 15 45·39	112 8
31 Pegasi	5	22 16 17·99	78 20
σ^2 Aquarii	4-3	23 3 47·62	111 45
υ Pegasi	5-4	23 20 5·24	67 11
ω^1 Aquarii	5-6	23 34 17·18	104 48
20 Piscium	6-5	23 42 29·54	93 21

Radcliffe Observatory, Oxford:
1894 *June* 7.

On the R—D Discordance. By Professor H. H. Turner, M.A., B.Sc.

(*Abstract.*)

1. The following is a brief abstract of a paper by Mr. W. G. Thackeray and myself, which will shortly appear in the *Memoirs*.

2. Various researches have been undertaken by us in recent years with the view of elucidating questions connected with the R—D discordance. These have resulted in showing—

First, that the cause of the discordance can *not* be traced in one or two directions already suggested as probably the right ones.

Secondly, that there is a direction, so far as we know not hitherto indicated, in which the cause may be sought, though we have not so far been able to complete the elucidation. This completion may very possibly involve considerable labour and demand further ingenuity; and as I have now left the Royal Observatory, it seems fitting that the results of our joint labours should be recorded without further delay.

3. In the *Memoirs* attention is first briefly called to the manner of making reflexion observations of stars. The R observation precedes the D observation, except for close circumpolar stars.

4. It is pointed out that there are limiting zenith distances, beyond which reflexion observations are untrustworthy owing to the cutting off of part of the object-glass. These are roughly Z.D. 20° to 36° until 1882, and Z.D. 22° to 65° subsequently.

5. The history of the discordance for the Greenwich transit circle is traced *de novo*: that is to say, the original observations are collected and rediscussed from 1851 to 1890. It is concluded that—

(α) The discordance has increased in amount during this period.

(β) For zenith distances 22° to 36°, which are available for all years from 1851–1890, the discordance is more nearly constant than the law sine zenith distance would allow, but is sensibly symmetrical on both sides of the zenith.

(γ) The period 1866–1870 is anomalous in these respects.

6. From 1882 a much larger range in zenith distance has been available for reflexion observations, and the law of increase of R—D with zenith distance can thus be examined in greater detail. The adopted formula 1″·3 sin Z.D. increases too rapidly at small and not rapidly enough at large zenith distances, the errors of formula being approximately as follows:

Z.D.	Error of Formula.	Z.D.	Error of Formula.
°	″	°	″
25	+0·06	45	+0·12
30	+0·20	50	+0·03
35	+0·28	55	−0·21
40	+0·26	60	−0·28

7. The *first* possible source of the discordance which calls for mention is ordinary flexure of the telescope as indicated by the collimators. A series of observations was made to determine this instrumental constant between March and July 1893. In all 184 determinations were made, the mean value being +0″·15. This coefficient is quite inconsistent with the explanation of an R—D discordance of 1″·3 sin Z.D. as ordinary flexure.

The results were incidentally arranged according to the external

temperature at the time of observation as follows, suffixes indicating number of observations:

Temp.	44°	48°	52°	58°	62°	67°	75°
	"	"	"	"	"	"	"
Flexure	-0.02_6	$+0.09_{12}$	$+0.04_{16}$	$+0.14_{25}$	$+0.19_{43}$	$+0.20_{39}$	$+0.35_{32}$

8. The assumption that the R—D discordance indicates a correction applicable equally but in opposite directions to R and D observations is briefly commented upon.

9. It is remarked that the R—D discordance has already been shown to have an annual variation (*M. N.* lii. 5).

10. The *second* possible source of the discordance dealt with is irregular refraction owing to heated air near the instrument. It was recently shown (*M. N.* liii. p. 424) that the excess of internal temperature is greater when the external temperature is below the average, and less when above. As an approximate numerical result it was concluded in that paper that any phenomenon depending upon the heated strata of air near the instrument *should disappear when the external temperature is* 13° *above the average, and be doubled when the external temperature is about* 13° *below the average.*

Now an analysis of the results for R—D for seven years shows that the R—D discordance is *sensibly the same for temperatures above and below the average*; and it is concluded that the chief source of the R—D discordance is *not to be sought in irregular refraction near the instrument.*

Some importance is attached to this conclusion.

11. We now come to the line of investigation which it is hoped will lead to a solution of the problem.

12. It was found that the observations of a star made in the "direct" position of the telescope, but after a reflexion observation, differed systematically from the "direct" observations made in the ordinary course. After some trouble in clearing the effects of error in adopted inclination of the horizontal wire, this systematic difference was found to be $0''.27$, zenith distances obtained in the ordinary course being the larger.

13. The question naturally arose, "What would be the effect of reversing the usual order of operations and taking the D observation before the R observation?"

Observations of 118 stars on eleven nights have given the answer that *the* R—D *discordance is reversed in sign when the order of the* R *and* D *observations is changed*, though its new value is not quite so large as the old.

14. It would appear that this result must be not only a clue, but a key to the problem. But for some reason the key does not yet turn in the lock.

Some Measures of Photographs of the Pleiades at the Oxford University Observatory. By Professor H. H. Turner, M.A., B.Sc.

1. The late Professor Pritchard directed his assistants to take a number of photographs of the *Pleiades* with the Astrographic Equatorial, to be accurately measured with the micrometer. His original intention was to discuss the results for relative parallax of the individual stars; while he expected at the same time to gain experience in the measurement and reduction of stellar photographs taken with this instrument, for use in discussing the plates of the Astrographic Chart. Various difficulties arose in the course of the work, which made him doubtful of being able to carry out satisfactorily his original schemes; but he expressed the hope that "at all events the attempt would issue in a catalogue of the coordinates of all the stars therein up to magnitude 12" (*Monthly Notices*, vol. liii. p. 249).

2. On being appointed to succeed Professor Pritchard, it was one of my first cares to examine the actual state of this work, the latest initiated by him. The Radcliffe Observer, who had kindly undertaken the supervision of the work of the University Observatory in the interval between the death of Professor Pritchard and the appointment of a successor, had very naturally directed that this work should be continued without change on the lines laid down by my illustrious predecessor.

3. The following is a brief statement of the position of the work as I found it at the end of 1893 December.

Seventy plates of the *Pleiades* group had been taken between 1892 August 11 and 1893 March 4.

Three plates had been completely measured in a micrometer constructed by Messrs. Troughton and Simms, furnished with a micrometer screw (in one coordinate only) reading to $0^{mm}\cdot01$ ($0^{mm}\cdot001$ by estimation): all stars visible within a radius of 40′ from *Alcyone* having been measured by reference to the *réseau* lines: viz.—

Plate 252, exposed for 6^m on 1892 December 12;
„ 259, „ 7^m „ „ „ 13;
„ 294, „ 2^m „ 1893 February 10;

also a few of the brightest stars on plates 120, 121, 128, 129, 151, 152, 153, and 258, but the measures of these eight plates were made with a different micrometer furnished with ten wires.

Reductions.—The focal length of the telescope (or scale in arc of the photograph) had been discussed for eight plates; the orientation for nine plates; and the rectilinear measures of a few stars had been corrected for refraction, precession, aberration and

nutation, converted into differences of R.A. and Decl. from *Alcyone*, and compared with the corresponding differences found by Elkin with the heliometer in 1885, reduced to the epoch 1892·0.

But as not more than ten to fifteen stars had been measured, except on plates 252, 259, and 294, I thought it desirable to discuss these three plates first, before having time spent upon the completion of the measurement of the other plates.

4. It further appeared that this work had occupied considerable time; and that, if the original intention of Professor Pritchard were carried out completely, the pressing work of dealing in some way or other with the accumulated photographs of the Astrographic Chart must be delayed for some years.

5. I therefore decided to terminate this work (which I believe Professor Pritchard only meant to be preliminary to that of dealing with the Chart photographs) as speedily as possible, so far as was consistent with making a proper use of the time already expended. The method of reduction of the plates, by differences of R.A. and Decl., which had been found very tedious and not free from pitfalls, was at once changed for that of discussion in rectilinear coordinates such as I have recently suggested (*Monthly Notices*, vol. liv. p. 11). As a consequence, the reductions of the three plates which had been more fully measured were rapidly completed, and the results which follow will, I hope, be found of value from three points of view :

(1) As throwing further light on the accuracy to be reasonably expected from measures of stellar photographs.

(2) As giving a series of relative positions of the *Pleiades* at the epoch in question.

(3) As illustrating some advantages of the method of discussion by rectilinear coordinates, which I think have not hitherto been sufficiently recognised.

6. The method of reduction adopted may be briefly explained as follows. The positions of the stars given by Elkin for 1885·0* were brought up to 1892·0, and were used to find the quantities

$$\xi = \frac{180 \times 60}{\pi} \cdot \frac{\tan (\alpha - A) \sin q}{\cos (P - q)}, \qquad \eta = \frac{180 \times 60}{\pi} \cdot \tan (P - q);$$

where

A, P are the R.A. and N.P.D. of *Alcyone*,

α, p „ „ „ of any other star,

and $\tan q = \tan p \cdot \cos (\alpha - A)$.

[In practice these formulæ may be simplified into approxi-

* *Transactions of the Yale University Observatory*, vol. i. part 1, pp. 86 and 87.

mate formulæ ; but I give them in their geometrical form, as quoted in my paper above referred to.]

ξ and η are thus the rectangular coordinates which any star would have with reference to *Alcyone* on a photographic plate free from all errors, with *Alcyone* at its centre ; the coordinates being measured parallel and perpendicular to the equator respectively, and expressed in minutes of arc. Our actual plate is affected by refraction and aberration ; the coordinates are measured only approximately in the proper directions, and we only know the scale value approximately. Further, there are accidental deviations from flatness in the plate, and optical and photographic distortions. These last we must neglect as accidental, but all the former we may consider sensibly allowed for by linear corrections. If x, y be the measured coordinates of a star in millimetres, and affected with the above sources of error, then

$$x-\xi = a\xi + b\eta + c$$
$$y-\eta = d\xi + e\eta + f,$$

where a, b, c, d, e, f are six constants for the plate, whose values are small. Theoretically the six measured coordinates of three stars are sufficient to give these six constants ; but practically it is better to use many or all the measures, and solve the resulting equations by least squares or an equivalent process.

7. Thus the places given by Elkin having once been converted into ξs and ηs, all we have to do is to form the differences $x-\xi$, $y-\eta$ for the stars on any plate, and solve a series of equations of the above form. It will be remarked that the coefficients of a, b, c, d, e, f on the right of the equations are ξ, η, 1, and are thus the same for all plates and for both sets of equations. Much of the arithmetic in this particular case of measuring several plates of the same region can therefore be saved. This advantage is gained by starting with the *given* places (Elkin's) and reducing them to compare with the measured. It disappears when we start with the measured places (varying for each plate) and work back to the given places.

8. Having got a, b, c, d, e, f, the formation of the quantities

$$r_x \equiv x-\xi-(a\xi+b\eta+c)$$
$$r_y \equiv y-\eta-(d\xi+e\eta+f)$$

is very simple, and r_x, r_y then represent proper motion + accidental error for any star. If stars not given by Elkin are measured on the plate, we can deduce their positions (ξ, η) as they would be on his system from the equations

$$x = (1+a)\xi + b\eta + c$$
$$y = d\xi + (1+e)\eta + f,$$

or rather their equivalents

$$\Delta . \xi = (1+e)\, x - by - c\,(1+e) + hf$$
$$\Delta . \eta = -dx + (1+a)\, y - f\,(1+a) + cd,$$

where

$$\Delta = 1 + a + e + ac - bd,$$

which, if a, b, c, &c., are small, become sensibly

$$\xi = (1-a)\, x - by - c$$
$$\eta = -dx + (1-e)\, y - f.$$

9. In the following table (Table I.) are given :

Column 1. The star's number in Elkin's paper above referred to (*Transactions of the Yale University Observatory*, vol. i. part 1, pp. 86 and 87).

Columns 2 and 6. The coordinates ξ and η, representing the rectangular coordinates of a star on a perfect plate with *Alcyone* as centre, according to Elkin's places.

Columns 3 to 5. The simple differences between the measured coordinates in the ξ direction on each plate, and those on a hypothetically perfect plate as above.

Columns 7 to 9. The similar differences for the η coordinates.

TABLE I.

No. in Elkin.	ξ 1892·0.	$x-\xi$ Plate 252.	$x-\xi$ Plate 259.	$x-\xi$ Plate 294.	η 1892·0.	$y-\eta$ Plate 252.	$y-\eta$ Plate 259.	$y-\eta$ Plate 294.
	′	″	″	″	′	″	″	″
3	−42·345	−0·326	−0·340	−0·330	+ 1·363	−0·003	−0·012	+0·080
5	−36·760	−0·276	−0·303	−0·270	+10·803	+0·062	+0·052	+0·136
6	−35·722	−0·271	−0·291	−0·290	+ 0·238	−0·016	+0·004	+0·059
7	−32·578	−0·239	−0·276	−0·235	+ 9·263	+0·052	+0·044	+0·135
8	−32·684	−0·252	−0·236	−0·295	−24·389	−0·202	−0·212	−0·126
10	−31·286	−0·235	−0·275	−0·209	+21·495	+0·168	+0·160	+0·219
13	−28·029	−0·212	−0·217	−0·221	− 4·413	−0·046	−0·056	+0·017
14	−26·290	−0·194	−0·227	−0·163	+21·287	+0·154	+0·145	+0·208
15	−25·931	−0·190	−0·211	−0·197	− 1·515	−0·031	−0·029	+0·028
17	−25·480	−0·184	−0·218	−0·178	+13·629	+0·092	+0·090	+0·147
18	−25·053	−0·179	−0·223	−0·135	+31·132	+0·236	+0·223	+0·277
19	−24·645	−0·184	−0·203	−0·164	+10·817	+0·073	+0·061	+0·123
20	−22·804	−0·183	−0·199	−0·155	+15·574	+0·132	+0·105	+0·168
21	−22·208	−0·169	−0·172	−0·175	− 4·157	−0·042	−0·049	+0·002
22	−21·768	−0·161	−0·198	−0·137	+26·789	+0·197	+0·196	+0·233
23	−19·838	−0·143	−0·179	−0·116	+25·202	+0·186	+0·173	+0·224
24	−17·222	−0·125	−0·154	−0·126	+ 5·276	+0·030	+0·035	+0·070
25	−16·710	−0·129	−0·149	−0·125	+ 4·942	+0·022	+0·030	+0·063
26	−15·788	−0·136	−0·119	−0·140	− 9·539	−0·081	−0·074	−0·062

No. in Elkin.	ξ 1892·0.	$x-\xi$ Plate 252.	$x-\xi$ Plate 259.	$x-\xi$ Plate 294.	η 1892·0.	$y-\eta$ Plate 252.	$y-\eta$ Plate 259.	$y-\eta$ Plate 294.
27	−14′·173	−0′·098	−0′·122	−0′·096	+ 8′·869	+0′·058	+0′·055	+0′·090
28	−12·298	−0·090	−0·072	−0·131	−28·971	−0·242	−0·242	−0·210
29	−11·348	−0·081	−0·107	−0·085	− 0·209	−0·014	−0·021	+0·010
30	− 6·986	−0·041	−0·096	−0·018	+24·840	+0·181	+0·187	+0·198
32	− 5·617	−0·038	−0·057	−0·052	− 6·640	−0·072	−0·060	−0·055
33	− 4·432	−0·025	−0·060	−0·012	+10·251	+0·076	+0·079	+0·083
34	− 4·140	−0·037	−0·033	−0·066	−19·493	−0·161	−0·149	−0·145
35	− 2·868	−0·025	−0·027	−0·025	+ 1·363	+0·001	+0·014	+0·017
36	− 2·411	−0·028	−0·017	−0·060	−22·760	−0·199	−0·182	−0·174
37	− 2·228	−0·028	−0·036	−0·032	+ 2·015	−0·003	+0·020	+0·017
38	− 1·840	−0·016	−0·017	−0·019	+ 0·648	+0·001	+0·011	+0·005
39	− 1·682	−0·012	−0·008	−0·032	−18·122	−0·152	−0·136	−0·150
40	− 1·420	+0·005	−0·047	+0·042	+28·989	+0·206	+0·228	+0·225
41	− 0·857	−0·008	−0·051	+0·046	+33·122	+0·247	+0·274	+0·261
42	− 0·956	+0·030	−0·006	−0·023	−11·439	−0·099	−0·076	−0·092
43	− 0·275	+0·001	+0·013	−0·038	−25·611	−0·209	−0·193	−0·201
44	− 0·017	+0·007	−0·014	+0·015	+10·995	+0·076	+0·085	+0·082
46	+ 2·016	+0·030	+0·044	−0·022	−29·718	−0·248	−0·225	−0·236
47	+ 3·349	+0·014	+0·042	−0·026	−33·687	−0·281	−0·251	−0·271

No in Elkin.	ξ 1892·0.	$x-\xi$ Plate 252.	$x-\xi$ Plate 259.	$x-\xi$ Plate 294.	η 1892·0.	$y-\eta$ Plate 252.	$y-\eta$ Plate 259.	$y-\eta$ Plate 294.
49	+10′010	+0′084	+0′059	+0′101	+12′899	+0′090	+0′113	+0′085
50	+ 8·667	+0·077	+0·064	+0·076	+ 2·300	+0·006	+0·037	+0·005
51	+12·260	+0·092	+0·113	+0·035	−40·910	−0·325	−0·300	−0·335
52	+13·763	+0·110	+0·082	+0·131	+14·562	+0·104	+0·132	+0·094
53	+14·944	+0·121	+0·103	+0·127	+ 4·717	+0·032	+0·049	+0·010
54	+20·174	+0·166	+0·162	+0·138	−14·638	−0·125	−0·098	−0·153
55	+23·010	+0·181	+0·171	+0·171	− 2·850	−0·032	+0·010	−0·057
56	+23·281	+0·187	+0·180	+0·187	+ 2·159	+0·004	+0·048	−0·041
57	+23·693	+0·187	+0·186	+0·163	−12·838	−0·114	−0·075	−0·144
58	+24·356	+0·196	+0·172	+0·221	+17·733	+0·129	+0·164	+0·093
59	+25·497	+0·206	+0·176	+0·225	+16·837	+0·118	+0·155	+0·093
60	+26·556	+0·223	+0·200	+0·226	+ 8·854	+0·058	+0·092	+0·024
61	+27·984	+0·218	+0·173	...	+31·728	+0·231	+0·279	...
62	+31·004	+0·241	+0·249	+0·200	−23·239	−0·191	−0·151	−0·230
63	+31·158	+0·244	+0·210	+0·260	+ 8·714	+0·063	+0·108	+0·023
64	+33·157	+0·259	+0·246	+0·277	+ 7·103	+0·058	+0·109	+0·016
65	+33·460	+0·254	+0·242	+0·283	+15·025	+0·104	+0·152	+0·064
66	+34·208	+0·273	+0·255	+0·246	−14·986	−0·127	−0·072	−0·173

Plate 294, No. 61, the image excessively faint.

10. To find the coefficients a, b, c, d, e, f, the following four groups of stars were selected :

Nos.	3, 5, 6, 7, 13, 15, 21	=	Group I.
„	30, 40, 41	=	„ II.
„	34, 43, 46, 47	=	„ III.
„	55, 56, 60, 63, 64	=	„ IV.

The mean coordinates of each group are roughly as follows :

Group	I.	$-30'$	$0'$
„	II.	0	$+30$
„	III.	0	-30
„	IV.	$+30$	0

the four resulting equations being thus well adapted to the determination of the quantities a, b, c, d, e, f.

11. Although scarcely necessary, an example may perhaps be given of the formation of one pair of the equations ; say that for Plate 252, Group I. :

No. in Elkin.	ξ	$x-\xi$	η	$y-\eta$
3	$-42'345$	$-0'326$	$+ 1'363$	$-0'003$
5	$-36{\cdot}760$	$-0{\cdot}276$	$+10{\cdot}803$	$+0{\cdot}062$
6	$-35{\cdot}722$	$-0{\cdot}271$	$+ 0{\cdot}238$	$-0{\cdot}016$
7	$-32{\cdot}578$	$-0{\cdot}239$	$+ 9{\cdot}263$	$+0{\cdot}052$
13	$-28{\cdot}029$	$-0{\cdot}212$	$- 4{\cdot}413$	$-0{\cdot}046$
15	$-25{\cdot}931$	$-0{\cdot}190$	$- 1{\cdot}515$	$-0{\cdot}031$
21	$-22{\cdot}208$	$-0{\cdot}169$	$- 4{\cdot}157$	$-0{\cdot}042$
Mean	$-31{\cdot}9390$	$-0{\cdot}2404$	$+ 1{\cdot}6546$	$-0{\cdot}0034$

The resulting equations are thus—

$$-31{\cdot}9390a + 1{\cdot}6546b + c = -0'2404$$
$$-31{\cdot}9390d + 1{\cdot}6546e + f = -0{\cdot}0034$$

For the same group in other plates, columns 2 and 4 need not be repeated.

12. The following Table II. gives a summary of the numbers entering into the equations. The coefficients of a and b (or of d and e) are given in the second and third columns ; the means of $x-\xi$ in columns 4 to 6, and the means of $y-\eta$ in columns 7 to 9.

TABLE II.

Group.	Coefficient of a or c.	Coefficient of b or d.	Mean $x-\xi$.			Mean $y-\eta$.		
			Pl. 252.	Pl. 259.	Pl. 294.	Pl. 252.	Pl. 259.	Pl. 294.
I.	−31·9390	+ 1·6546	−0·2404	−0·2586	−0·2454	−0·0034	−0·0069	+0·0653
II.	− 3·0877	+28·9837	−0·0147	−0·0647	+0·0233	+0·2113	+0·2297	+0·2280
III.	+ 0·2375	−27·1273	+0·0020	+0·0165	−0·0380	−0·2247	−0·2045	−0·2132
IV.	+27·4324	+ 4·7960	+0·2188	+0·2014	+0·2242	+0·0302	+0·0734	−0·0070

13. The resulting values of a, b, c, d, e, f are given in Table III. below :

TABLE III.

Plate.	a	b	c	d	e	f
252	+0·00773	+0·00016	−0·00535	+0·00015	+0·00778	+0·01257
259	+0·00780	−0·00099	+0·00992	+0·00094	+0·00780	−0·00838
294	+0·00783	+0·00155	−0·00218	−0·00163	+0·00777	+0·00090

14. Substituting these values in the expressions

$$r_x \equiv x-\xi-(a\xi+b\eta+c)$$
$$r_y \equiv y-\eta-(d\xi+e\eta+f)$$

we get the values for r_x and r_y, shown in Table IV. ; the values being shown in seconds of arc as a more familiar unit for small quantities.

TABLE IV.

Name or No. in Elkin.		Plate 252 r_x	Plate 259 r_x	Plate 294 r_x	Mean.	Plate 252 r_y	Plate 259 r_y	Plate 294 r_y	Mean.
	3	+0·21	−0·02	+0·08	+0·09	−0·24	−0·69	−0·12	−0·35
Celæno	5	−0·12	−0·23	−0·02	−0·12	+0·34	+0·21	+0·31	+0·29
Electra	6	−0·04	+0·19	+0·70	−0·28	+0·10	−1·79	−0·05	−0·58
	7	−0·41	+0·20	−0·29	−0·17	+0·24	+0·21	−0·69	−0·08
	8	−0·02	−0·23	+0·13	−0·04	−0·20	−0·19	−0·72	−0·37
Taygeta	10	+0·04	+0·02	−0·10	−0·01	−1·00	−0·95	−0·15	−0·70
	13	−0·05	−0·37	−0·29	−0·24	−0·20	+0·07	−0·44	−0·19
	14	−0·10	−0·51	−0·53	−0·38	−0·19	+0·14	−0·08	−0·04
	15	−0·36	+0·08	−0·45	−0·24	+0·27	−0·08	+0·05	+0·08
	17	−0·40	−0·22	+0·03	−0·20	−0·06	−0·07	−0·08	−0·07
	18	−0·34	−0·78	−0·73	−0·62	−0·52	+0·11	+0·23	−0·06
	19	−0·02	−0·52	−0·68	−0·41	−0·20	+0·42	−0·04	+0·06
Maia	20	+0·83	−0·21	+0·10	+0·24	−1·50	+0·07	−0·68	−0·70
	21	+0·05	−0·37	−0·26	−0·19	−0·27	+0·10	+0·02	−0·05
Asterope *k*	22	+0·08	−0·43	+0·54	+0·06	−0·15	−0·09	+0·55	+0·10
„ *l*	23	−0·11	−0·58	+0·04	−0·22	−0·22	+0·65	+0·16	+0·20
	24	−0·18	+0·32	+0·02	+0·05	−0·15	−0·25	−0·15	−0·18
	25	+0·29	+0·28	+0·17	+0·25	−0·18	−0·08	+0·07	−0·06
Merope	26	+1·00	−0·23	+0·15	−0·31	−0·38	−0·56	+0·72	−0·07
	27	−0·38	−0·41	−0·02	−0·27	−0·12	+0·41	+0·03	+0·11
	28	−0·32	−0·24	−0·56	−0·37	+0·23	+0·62	+0·20	+0·35
	29	−0·12	+0·60	−0·19	+0·10	−0·01	+0·88	+0·32	+0·40
	30	−0·28	+0·46	+0·16	+0·11	+0·02	+0·34	+0·27	+0·21
	32	−0·13	+0·64	−0·08	+0·14	+0·50	+0·53	+0·65	+0·56

Name or No. in Elkin.		Plate 252 r_x	Plate 259 r_x	Plate 294 r_x	Mean.	Plate 252 r_y	Plate 259 r_y	Plate 294 r_y	Mean.
	33	−0″25	+0″37	−0″35	−0″08	−0″47	+0″18	+0″13	−0″05
	34	+0·37	+0·67	+0·26	+0·43	−0·15	−0·07	−0·07	−0·10
	35	+0·43	−0·35	+0·33	+0·14	−0·10	−0·01	−0·20	−0·10
	36	+0·60	+0·71	+0·40	+0·57	+0·62	+0·47	−0·04	+0·35
	37	+0·91	+0·45	+1·11	+0·82	+0·45	−0·02	+0·04	+0·16
	38	+0·37	−0·42	+0·39	+0·11	−0·43	−0·10	+0·08	−0·15
	39	+0·02	+0·23	−0·50	−0·08	0·00	−0·05	+0·64	+0·20
	40	−0·43	−0·13	−0·43	−0·33	+0·51	+0·16	+0·04	+0·24
	41	+0·65	+0·13	−0·03	+0·25	−0·03	−0·64	−0·24	−0·30
	42	−0·48	+0·05	−0·08	−0·17	−0·05	−0·47	+0·20	−0·11
	43	−0·18	+0·08	−0·18	−0·09	−0·07	−0·07	+0·05	−0·03
	44	−0·07	−0·38	+0·17	−0·09	−0·08	+0·40	+0·11	+0·15
Alcyone		+0·25	−0·55	+0·05	−0·08	−0·65	+0·35	−0·10	−0·05
	46	−0·90	−0·46	−0·44	−0·60	+0·38	+0·07	+0·02	+0·16
	47	+0·64	−0·08	+0·05	+0·20	+0·52	−0·17	+0·13	+0·16
	49	−0·02	−0·17	−0·10	−0·10	+0·07	+0·17	−0·16	+0·03
	50	−0·33	−0·47	−0·22	−0·34	+0·14	−0·31	−0·17	−0·11
	51	0·00	+0·88	+1·80	+0·89	−0·13	−0·10	−0·26	−0·16
	52	+0·16	+0·12	+0·02	+0·10	+0·06	−0·05	−0·28	−0·09
	53	−0·04	−0·04	−0·11	−0·06	−0·24	+0·46	+0·06	+0·09
	54	−0·48	+0·07	−0·11	−0·17	+0·21	+0·54	+0·31	+0·35
Atlas	55	+0·03	+0·13	+0·34	+0·17	+0·14	−0·28	−0·25	−0·13
Pleione	56	−0·14	−0·57	−0·03	−0·25	+0·33	−0·20	+1·09	+0·41
	57	−0·10	+0·16	+0·21	+0·09	+0·42	+0·20	+0·26	+0·29
	58	−0·05	−0·51	−0·11	−0·22	+0·09	+0·19	+0·19	+0·16
	59	−0·12	−0·18	+0·10	−0·07	+0·36	+0·35	−0·34	+0·12
	60	−0·70	−0·63	−0·20	−0·51	+0·24	+0·47	−0·06	+0·22
	61	+0·46	+0·28	...	+0·37	+0·54	+0·03	...	+0·28
	62	−0·05	+0·41	+0·46	+0·27	+0·25	+0·30	−0·15	+0·13
	63	+0·12	+0·94	−0·10	+0·32	−0·08	−0·29	−0·46	−0·28
	64	+0·15	−0·24	−0·33	−0·14	−0·52	−0·99	−0·98	−0·83
	65	+0·70	−0·29	−0·11	+0·10	+0·42	+0·14	−0·21	+0·12
	66	−0·41	+1·06	−0·03	+0·21	+0·28	−0·41	−0·05	−0·06

15. Since my conviction that the above process is as valid as it is simple may not be shared by others, it would seem advisable to add a few words in defence of the process.

16. The most striking difference between the above method of reduction and those commonly employed is that in the latter

various corrections, such as those for refraction and aberration, are first applied to the measures; that the scale value and orientation of the plate are also separately considered and the proper corrections applied; while in the above reductions all these are (not *neglected*, but) deduced *en bloc* from the measures themselves.

17. Let us consider this difference a little more in detail.

If x and y be the measured coordinates of any star, the refraction correction may be expressed by the formula

$$\delta_1 x = R_1 x + R_2 y,\ \delta_1 y = R_3 x + R_4 y.$$

Various expressions may be given for R_1, R_2, R_3, R_4, but it is only necessary to note that they are constant over the plate, the zenith-distance not being too large.

Similarly the corrections for aberration, &c., may be written

$$\delta_2 x = A_1 x + A_2 y,\ \delta_2 y = A_3 x + A_4 y.$$

The correction for scale value may be written

$$\delta_3 x = Sx,\ \delta_3 y = Sy$$

if we consider the scale value equal in all directions; and that for orientation

$$\delta_4 x = Mx + Ny,\ \delta_4 y = -Nx + My,$$

where

$$M^2 + N^2 = 1.$$

Finally, the correction for error of centring is

$$\delta_5 x = F,\ \delta_5 y = G,$$

assuming that the plate is normal to the axis of the telescope.

Thus the ordinary process of direct correction for such systematic errors would reduce our measures x and y to the following corrected values:

$$\left.\begin{aligned} X &\equiv x + (R_1 + A_1 + S + M)x + (R_2 + A_2 + N)y + F \\ Y &\equiv y + (R_3 + A_3 - N)x + (R_4 + A_4 + S + M)y + G \end{aligned}\right\} \quad \ldots \quad (1)$$

18. If all the quantities $R_1 R_2 \ldots$, $A_1 A_2 \ldots$, S, M, N are considered *completely determined*, then the measures are now finally corrected, and the residuals obtained by converting them into R.A. and N.P.D. and comparing them with known stars must be considered free from systematic error. But though the coefficients $R_1 R_2 \ldots$ and $A_1 A_2 \ldots$ may be calculated with sufficient accuracy, this is generally not the case with S, M, and N. It is very difficult, if not impossible, to determine the scale value of the plate and its orientation *independently of the measures made on the actual stars*. In short, most investigators have hitherto considered that the above corrected measures, X and Y, are affected with small systematic errors $r_1 x + r_2 y + r_3$, $r_4 x + r_5 y + r_6$, the coefficients r_1, r_2, &c., being determined from

the known stars. They have, in fact, solved a series of equations of the form

$$\left.\begin{aligned} r_1x+r_2y+r_3&=X-\xi \\ r_4x+r_5y+r_6&=Y-\eta \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (2)$$

where ξ and η are, as above, the coordinates of the known stars.

19. Now, once the necessity for this final correction of the plate is admitted, the labour expended in applying the above *direct* corrections as a preliminary must rank as useless. If we form, as above, the differences $x-\xi$, $y-\eta$ between the uncorrected measures x, y and the known coordinates ξ, η and solve the equations

$$\left.\begin{aligned} s_1x+s_2y+s_3&=x-\xi \\ s_4x+s_5y+s_6&=y-\eta \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (3)$$

by the same process (of least squares or otherwise) by which we ultimately solve equations (2), we should find

$$\left.\begin{aligned} s_1&=r_1-(R_1+A_1+S+M) \\ s_2&=r_2-(R_2+A_2+N) \\ s_3&=r_3-F \\ &\&c. \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (4)$$

that is to say, the total corrections applicable to the measures would be found exactly the same as before. We can see this at once by substituting for X, Y on the right of equations (2) their values from equations (1), thus obtaining

$$r_1x+r_2y+r_3=x-\xi+(R_1+A_1+S+M)x+(R_2+A_2+N)y+F$$
$$r_4x+r_5y+r_6=y-\eta+(R_2+A_2-N)x+(R_4+A_4+S+M)y+G,$$

which may be rewritten

$$\{r_1-(R_1+A_1+S+M)\}x+\{r_2-(R_2+A_2+N)\}y+r_3-F=x-\xi$$

and

$$\{r_4-(R_2+A_2-N)\}x+\{r_5-(R_1+A_4+S+M)\}y+r_6-G=y-\eta,$$

and on comparing these with equations (3), viz.,

$$s_1x+s_2y+s_3=x-\xi$$
$$s_4x+s_5y+s_6=y-\eta$$

we see that

$$s_1=r_1-(R_1+A_1+S+M)$$
$$s_2=r_2-(R_2+A_2+N)$$
$$\&c.\ \&c.$$

Hence, as far as the final correction of the plate is concerned, we get precisely the same result by solving equations (3) at once as by laboriously first correcting the measures and then treating the

residuals ; provided always that we cannot satisfactorily determine the scale value and orientation independently of the measures themselves.

20. It is my own opinion that the scale value and orientation can *not* be determined satisfactorily independently—that is to say, from other plates ; and I think this opinion is shared by others who have discussed such measures, especially MM. Loewy and Bakhuyzen.

By "independently" I should understand "from measures made on other plates" ; for it is to be remarked that anything attaching to the same plate can be included in the equations (3), with any weight considered advisable. For instance, a star trail which might be considered a determination of orientation independent of the measures is merely a series of stars of the same declination, and will furnish equations to determine s_1, s_2, s_3, &c., which may be included in the set (3). Similarly, if an experiment is made for scale value by impressing two images of the same star on the plate at a known interval, we have practically *two* known stars to be included in equations (3) instead of one.

21. It is to be further remarked that it is quite easy when once the coefficients s_1, s_2, s_3, &c., are obtained to analyse them into their constituent parts r_1, R_1, A_1, S_1M &c., if so desired. The coefficients R_1 R_2 . ., and A_1 A_2 . . must be calculated from the data as to the taking of the plate, and applied to s_1, s_2, &c., so that we find

$$\begin{aligned}
[s_1 + R_1 + A_1] &= r_1 - (S + M) \\
[s_2 + R_2 + A_2] &= r_2 - N \\
[s_3] &= r_3 - F \\
[s_4 + R_3 + A_3] &= r_4 + N \\
[s_5 + R_4 + A_4] &= r_5 - (S + M) \\
[s_6] &= r_6 - G.
\end{aligned}$$

If we assume $r_1 = r_2 = r_3 = r_4 = r_5 = r_6 = 0$, that is, that all the systematic errors are attributable to error of centring, orientation, and an unknown *but uniform* scale value, we have F and G determined ; and four equations to find the two quantities S + M and N.

If, however, we admit that the scale value may be different in different directions, we cannot separate the scale value from the orientation, and some of the small quantities r_1, r_2, r_4, r_5 must be retained. If the quantities in square brackets are found to be the same for different plates, we may assume that the scale value and orientation have remained sensibly constant.

22. The values of the coefficients in Table III. are deduced from a few selected stars only, which may be affected with large accidental errors or with large proper motions ; and hence the resulting formulæ may not be the best for the whole plate. But it is a well-known characteristic of linear equations that one

solution may be readily added to another, and hence we can improve our solution by treatment of the residuals given in Table IV. to any extent we choose.

For example, let us divide the stars *not* used in the above solution into four groups as follows—

Group V.: $(x-, y+)$; Nos. 10, 14, 17, 18, 19, 20, 22, 23, 24, 25, 27, 33, 35

Group VI.: $(x-, y-)$; Nos. 8, 26, 28, 29, 32, 36

Group VII.: $(x+, y-)$; Nos. 39, 42, 51, 54, 57, 62, 66

Group VIII.: $(x+, y+)$; Nos. 37, 38, 44, 49, 50, 52, 53, 58, 59, 61, 65

and form the mean coordinates and residuals for these groups, we find

TABLE V.

Group.	Mean ξ.	Mean η.	Mean x Residual. Plate 252.	Plate 259.	Plate 294.	Mean Plate.	Mean y Residual. Plate 252.	Plate 259.	Plate 294.	Mean Plate.
	′	′	″	″	″	″	″	″	″	″
V.	−19·428	+15·125	−0·01	−0·23	−0·09	−0·11	−0·37	+0·04	−0·02	−0·12
VI.	−13·358	−15·408	+0·17	+0·21	−0·02	+0·12	+0·13	+0·29	+0·19	+0·20
VII.	+16·957	−19·453	−0·21	+0·41	+0·25	+0·15	+0·14	0·00	+0·14	+0·09
VIII.	+14·054	+11·769	+0·18	−0·15	+0·11	+0·05	+0·13	+0·11	−0·07	+0·06

23. Let us now assume that these residuals can be corrected by an expression of the form $\gamma + \alpha\xi + \beta\eta$: then for the x residuals we have 4 equations (one for each group), to determine α and β for each plate. The equations from the first two groups are

$$\gamma - 19{\cdot}428\,\alpha + 15{\cdot}125\,\beta = -0''{\cdot}01,\ -0''{\cdot}23,\text{ or } -0''{\cdot}09 \text{ respectively,}$$

and

$$\gamma - 13{\cdot}358\,\alpha - 15{\cdot}408\,\beta = +0''{\cdot}17,\ +0''{\cdot}21,\text{ or } -0''{\cdot}02 \text{ respectively.}$$

Subtracting to eliminate γ we have

$$-6{\cdot}1\,\alpha + 30{\cdot}5\,\beta = -0''{\cdot}18,\ -0''{\cdot}44,\text{ or } -0''{\cdot}07 \text{ respectively.}$$

Similarly from Groups VII. and VIII. we get

$$-2{\cdot}9\,\alpha + 31{\cdot}1\,\beta = +0''{\cdot}39,\ -0''{\cdot}56,\text{ or } -0''{\cdot}14 \text{ respectively.}$$

Now the coefficients of these two equations are so nearly similar that, unless β is very small and α large, the quantities on the right ought to agree well if they denote real systematic errors. A difference such as that between $-''{\cdot}18$ and $+''{\cdot}39$ must mean that the errors are largely accidental.

Similarly, forming equations VIII.–V., and VII.–VI., we get

$$+33{\cdot}5\,\alpha - 3{\cdot}4\,\beta = +0''{\cdot}19,\ +0''{\cdot}08,\text{ or } +0''{\cdot}20$$
$$+30{\cdot}3\,\alpha - 4{\cdot}0\,\beta = -0''{\cdot}38,\ +0''{\cdot}20,\text{ or } +0''{\cdot}27.$$

And if we take the y residuals we get the following six pairs of quantities, which should, but do not generally, agree:

$-0''.50$, $-0''.25$, or $-0''.21$ (V.–VI.)	$+0''.50$, $+0''.07$, or $-0''.05$ (VIII.–V.)
-0.01, $+0.11$, or -0.21 (VIII.–VII.)	$+0.01$, -0.29, or -0.05 (VII.–VI.)

It seems almost unnecessary, therefore, to solve these equations, as it would appear that the limit of accuracy has been nearly reached.

24. It must be remembered that the errors of the *réseau*, the tilt of the plate, and the optical distortion have been neglected. There are also several other directions in which the measures under discussion might be improved which it is not necessary to discuss here. The present investigation is not intended to show the limit of accuracy which may be obtained from a photograph; rather is it intended to point out that, with labour which (in my opinion) considerably exceeds that which can be afforded for the measurement of a plate for the Astrographic Chart, we must be content to accept accidental errors of at least $\pm 0''.25$. How far these errors may be reduced by refined investigations is a question of the utmost importance, but one which those concerned with the completion of the Astrographic Chart must (in my opinion) resolutely put aside for the present.

25. On the other hand, I consider that it is shown by the above and similar discussions how very rapidly stellar positions may be obtained from the plates with an accuracy of about $\pm 0''.50$. After all, this does not compare unfavourably with the accuracy of the meridian observations which must form our basis of operations; and in the work for the Chart it is important to remember that the saving of a single figure for each star reduces the labour appreciably.

26. It is in favour of the work on the Chart plates that this investigation is here terminated for the present.

Photograph of the Cluster h VI. 37 *Argûs.*

By Isaac Roberts, D.Sc., F.R.S.

The photograph of the cluster h VI. 37 *Argûs*, R.A. $7^h\ 55^m$, Decl. 10° 20′ south, was taken with the 20-inch reflector on 1894 February 27, with exposure of the plate during 90 minutes, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The cluster is No. 2,506 in the *New General Catalogue* and No. 1,611 in the *General Catalogue*, where (p. 75) Sir J. Herschel describes it as pretty large, very rich, compressed, stars 11–20 mag.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, p. 63) records the results of nine observations made between the years 1849 and 1856, when he saw a spiral appearance by the brightest star, some unresolved milkiness about the central star, very curious black spaces, smaller stars so confused together as to give a nebulous look to parts of the cluster.

The photograph shows the cluster as a remarkable aggregation of faint stars in the midst of crowded surroundings of similar stars which cover the sky over several degrees. On the negative the cluster seems like an island in a sea, and the black spaces in it, referred to by Lord Rosse, are very conspicuous, and resemble those in the globular cluster Messier 13 *Herculis*. There are also branched lines and curves of stars very similar to those seen in globular clusters, but there is no indication whatever of nebulosity in this, as I always have found to be the case in globular clusters.

It puts little stress on the imagination to perceive in this cluster the progressive development of a globular cluster from a nebula or from meteorites, all the nebulosity being condensed into stars. Or we might take the converse of this, and assume that the stars are gravitating to a centre when they will collide and evolve nebulosity; but the first suggestion appears to me the more probable.

There are other examples of apparent similar developments; such, for instance, are the clusters H VI. 33, 34 *Persei* and Messier 11 *Antinoi*, which indicate the forms of globular clusters, but without the nebulosity. These inferences will be better appreciated if I now show by the lantern the original negatives of this cluster and of H VI. 33, 34 *Persei*, Messier 11 *Antinoi*, and M. 13 *Herculis*.

It will be seen that the resemblance which these clusters bear to the globular cluster is very striking, and impresses upon us the probability that such clusters as these and globular clusters have some close relationship in their origin like that herein suggested.

Photograph of the Nebulæ H V. 42 *and* H I. 176, 177 *Comæ Berenicis*. By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebulæ H V. 42 and H I. 176, 177 *Comæ Berenicis*, R.A. $12^h\ 38^m$, Decl. 33° 0′ north, was taken with the 20-inch reflector on 1894 March 29, with exposure of the plate during three hours, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The Nebula H V. 42

is No. 4,631 in the *New General Catalogue*, and No. 3,165 in the *General Catalogue*, where Sir J. Herschel describes it as a

remarkable object, very bright, very large, exceedingly extended 70°±, brighter in the middle with a nucleus, and a bright star near. In the *Phil. Trans.* 1833 he gives a drawing of it (Pl. XV. fig. 76) which shows the nebula extended to a fine point at each end, and it has a dense nebulous centre but no stars involved; a faint nebula (H II. 659) is visible near it on the *north preceding* side.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, p. 119) describes it as a most extraordinary object with a bright star near the centre, and to the right (*n*) masses of light appear through it in knots. A drawing of it is given in the *Phil. Trans.* 1850, Pl. XXXVII. fig. 9, which has several features resembling the photograph, but no stars are shown to be involved in it.

The photograph shows the nebula much resembling a mackerel in form and markings, the head being on the *following* and the tail at the *preceding* end. The margins are rugged, as shown on Lord Rosse's drawing, but the interior is a mixture of nebulous condensations and stars with fairly well-defined margins, seventeen of which I counted involved in the nebula, besides several condensations of nebulous matter. There is no certain central nucleus, though there is a bright star near the centre, touching the northern edge. The nebula seems to be a circle or an oval seen nearly edgewise, but with the southern edge a little elevated. The nebula H II. 659 is shown on the north side near it, with a stellar nucleus surrounded with nebulosity, and the bright star referred to by both Sir J. Herschel and Lord Rosse is also visible. The position angle of the nebula is given by Sir J. Herschel as about 70°, but the photograph shows it to be nearly on a parallel of declination.

The Nebulæ H I. 176, 177

are shown on the same photograph as H V. 42, and are numbered respectively 3,189 and 3,190 in the *General Catalogue*. The first (176) is described by Sir J. Herschel as a remarkable object, pretty bright, large, very much extended in the direction 34°·3, and is *south preceding* of two. The second (177) is described as a remarkable object, pretty faint, large, extended in the direction 90°± *north following* of two. In the *Phil. Trans.* for 1833, Pl. XV. fig. 75, a drawing is given which shows two patches of faint nebulosity crossing each other at their ends at an obtuse angle, but no structure or condensation of nebulosity is indicated in either of them.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, p. 120) states as the result of eleven observations that Herschel's two nebulæ form one, the joining part in the middle faint, and with faint prolongation of the nebula on the *south preceding* side. "Is like a caterpillar on a leaf," glimpses of bands seen, end turns up at an angle of 60°, suspected a continuation of shorter end curving back, *south preceding* nucleus very well defined.

The drawing given in the *Phil. Trans.* 1861, Pl. XXVIII. fig. 26, conveys a good idea of the form of the northern half of the nebula.

The photograph clearly confirms Lord Rosse that it is one, and not two nebulæ, and the four stars shown in his drawing are in the positions he indicates; two of them are very faint, and it is remarkable that he did not see the three other stars involved, which the photograph shows to be much brighter than the two he refers to. There is a bright star in the centre of the figure, with dense nebulosity on the *south following* side of it, and five fairly well defined stars are involved in the dense nebulosity of the bright *north following* half of the nebula, the end of which is, like a hook, turned towards the *south following* side. The *south preceding* half of the nebula is much fainter, and spreads out wider, than the other half, and there are some nebulous structures and three very faint star-like condensations in it. The nebula seems as if it were assuming a spiral form, and that there had been a collision on the *north following* half, with the effect of closing together the nebulous mass and forcing part of it in the *south following* direction.

Photograph of the Nebulæ M 65, 66 *and* H V. 8 *Leonis.*
By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebulæ M 65, 66 and H V. 8 *Leonis*, R.A. $11^h\ 14^m$, Decl. 13° 50′ north, was taken with the 20-inch reflector on 1894 February 28, with exposure of the plate during three hours forty minutes, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The Nebula M 65, *New General Catalogue*, 3,623, *General Catalogue*, 2,373,

is described by Sir J. Herschel as bright, very large, much extended in the direction 165°±, gradually brighter in the middle, with a nucleus; eight observations were made. In the *Phil. Trans.* for 1833, Pl. XIV. fig. 53, he gives a drawing, but it does not compare well with the photograph.

Lord Rosse (*Phil. Trans.* 1850, Pl. XXXVII. fig. 7) gives a drawing of the nebula, and on p. 512 states that it is resolvable, a spiral or an annular arrangement about it, no other portion resolved; and in the *Observations of Nebulæ and Clusters of Stars*, p. 95, he gives the results of eight observations made between the years 1849 and 1861, and states that he suspected seeing, at times, dark spaces on either side of the nucleus, and some mottling and stars sparkling in it. He also saw a star close *following* the nucleus, but did not see the curious ring which, he says, Sir J. Herschel saw.

Lassell (*Mem. R.A.S.* vol. xxxv. p. 43, and Pl. III. fig. 15) describes the nebula as faint, irregular, and formless, and suspected that he saw some stars in it. The drawing does not resemble the photograph.

The photograph shows the nebula to be a symmetrical ellipse with a well-defined stellar nucleus surrounded by dense nebulosity, in the midst of which is a spiral ring filled with nebulosity; and this, together with the nuclear condensations, are surrounded with two elliptical rings of nebulosity separated by a dark space. Five star-like condensations of nebulosity are involved in the rings, and one bright star is in the dark space between the rings on the *south following* side of the nucleus. The whole nebula is even more symmetrical than the Great Nebula in *Andromeda*, and is clearly of that type; but I have not before seen a spiral with a stellar nucleus, both of which are involved in the dense central nebulosity.

The Nebula M 66, *New General Catalogue*, 3,627, *General Catalogue*, 2,377,

is described by Sir J. Herschel as bright, very large, much extended in the direction 150°, much brighter in the middle, two stars *n. p.*, nine observations made. In the *Phil. Trans.* 1833, Pl. XIV. fig. 54, a drawing of it is given which in outline resembles the photograph, but the elongation is in the direction of about 180°.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, p. 95) describes it as a spiral, well resolved about the nucleus, but no other part, two stars involved in it, with others and knots of nebulosity suspected; could not resolve the nucleus. A marginal sketch is given and a drawing in the *Phil. Trans.* 1861, Pl. XXVII. fig. 16, where some spirals are shown, but the resemblance to the photograph is not evident. Eleven observations were made between the years 1848 and 1857.

The photograph shows the nebula to be an imperfect spiral with a well-defined stellar nucleus which forms the pole of the convolutions, involved in which I counted fourteen nebulous and star-like condensations. They are all involved in what appears suggestive of a state of transition into the perfect form of spiral nebulæ, several of which have been photographed, and some of them presented to the Society.

The Nebula H V. 8, *New General Catalogue*, 3,628, *General Catalogue*, 2,378,

is described by Sir J. Herschel as pretty bright, very large, very much extended in the direction 102°; and in the *Phil. Trans.* for 1833, Pl. XIV. fig. 51, a drawing is given, but it does not resemble the photograph.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*,

p. 95, and Pl. III. fig. 8) describes and delineates the nebula as pretty bright, extended, split into two parallel rays, the split extending its whole length, the *following* part being partially filled with faint nebulosity. Eight observations were made between the years 1848 and 1866. The drawing well represents the greater part of the nebula.

The photograph shows it like a nebulous ring viewed edgewise, with a large dense central condensation, and that the ring along its periphery is divided into two parts parallel with each other by a broad dark band, or ring, which shuts from view the light of the central condensation. The two extremities of the diameter of the supposed nebulous ring show expansions of the nebulosity, and there are two stars apparently involved in the faint nebulosity at the *south following* extremity.

I may add that the time is approaching, if it has not already arrived, when discussion concerning the developments of these gigantic celestial bodies may be profitably undertaken, for reliable evidence showing their forms and structures is rapidly accumulating.

The existing classification of the nebulæ into bright, faint, very faint, very large, &c., is much too indefinite a description of the objects as they are now depicted to us by photography. They will require a classification which will define the principal characteristics of their forms, structure, brightness, and their spectra.

Remarks on Dr. Roberts's Photographs of Star Clusters.

By E. B. Knobel.

In considering the photographs of Star Clusters which have been presented to the Society from time to time by Dr. Roberts, I have been repeatedly struck by the great difference in the appearance of the object in the photograph compared with the view in the telescope. Stars which were conspicuous in eye observation did not show the same prominence in the photograph, and the great variation of magnitude in stars in the same field of view was not apparent. At first I was inclined to consider this anomaly as due to the long exposure employed, which brought upon the photographic plate a vast number of stars not discernible to the eye, and thus the configuration and general appearance so familiar in the telescope might be masked; but this explanation seemed hardly to be borne out by more minute examination. The fact seemed evident that, so far from these photographs showing the stars in their true relative magnitude, as has been claimed, there is an untrue and unnatural uniformity in the magnitudes which required investigation.

At the last meeting of the Society Dr. Roberts exhibited a photograph of the nebula 74 Piscium, with which object I was

familiar, and of which I had made a drawing many years ago. I believed I had indicated the relative magnitude of stars in the drawing as they appear to the eye in the telescope. It was obvious on comparing it with the photograph that I had shown a wider range of magnitude than we should infer from the photograph, and that there was an equality about the photographic magnitudes at variance with the eye observations.

If we compare photographs of the same object taken by a refractor, and a reflector, the difference to which I call attention is most conspicuous, and the fact cannot be disputed. The refractor photographs present a portrait of the object as one is familiar with it in the telescope, whereas the others are puzzlingly unlike.

To obtain further information on this point, I have measured the diameters of a fair number of stars in Dr. Roberts's photographs and in photographs of the same objects taken with refractors, limiting the selection to those stars which have marked density in the silver deposit. The measurements were made with a glass micrometer ruled to 0·005 of an inch, employing a magnifier of long focus. In all cases the measurements were made from the paper reproductions and not from the negatives, but the results thus obtained may be considered as sufficiently accurate for the purposes of the present paper. In such work much difficulty is found in deciding what to measure, seeing that the size of some discs may be affected by halation, and in other cases the unsymmetrical image produced by the Newtonian reflector renders accurate measures uncertain, and consequently some discrimination has to exercised. For convenience of discussion the relative areas of the star discs, being the squares of the measured diameters, are given in terms of the smallest star selected in each case.

The photographs taken for comparison with those of Dr. Roberts are for the Pleiades, the beautiful photograph by MM. Henry which was engraved and published by the Paris Observatory, and a fine photograph recently taken by M. Trépied with the astro-photographic telescope of the observatory at Algiers. For the region in *Cygnus*, and for the cluster 35 Messier, I have used the well-known photographs of MM. Henry, which, however, have the peculiarity that they were made with a triple exposure; consequently, with the smaller star discs there is a little more uncertainty in the exact dimensions, but not sufficient to affect the general conclusions arrived at; for the nebula N.G.C. 1977 *Orionis*, a special photograph taken by the MM. Henry, the enlargement of which is nearly on the same scale as Dr. Roberts's photograph of the *Orion* nebula.

The star numbers are those of a provisional list, and have no reference to Bessel's or other catalogues.

Relative Areas of Star Discs in Photographs of the Pleiades.
By Henry, Trépied, and Roberts.

Star No.	Mag.		Henry.	Trépied.	Roberts.
39	6·4		25·00	32·11	4·00
3	6·7		21·39	28·44	4·00
32	6·6		20·25	28·44	4·41
2	6·9		20·25	25·00	4·00
42	6·9		18·06	21·80	4·00
6	6·6	Pickering.	16·00	21·80	4·00
7	7·5		14·06	16·co	3·61
17	7·5		13·14	14·70	3·24
19	7·9		13·14	12·25	3·24
27	7·4		12·25	20·25	4·00
35	8·0		12·25	13·44	2·56
9	8·1		11·39	12·25	2·56
25	7·8		11·39	16·co	3·61
24	9		7·56	7·11	2·25
36	9		6·25	5·44	1·96
40	9		6·25	5·76	1·82
5	10		5·06	4·70	2·25
12	10		6·25	(·25	1·96
18	10		4·51	2·05	1·96
8	10		5·06	4·70	2·89
37	10		4·00	3·36	1·69
41	10		3·51	2·25	1·32
30	11		2·25	1·80	1·44
31	11		2·25	1·80	1·00
38	11	Henry.	2·25	1·00	1·00
16	11		2·25	1·80	1·69
34	11		2·25	1·00	1·00
4	11		2·25	1·36	1·21
28	11		1·56	1·00	1·21
29	11		1·56	1·00	1·21
33	11		1·89	1·14	1·00
23	11		1·56	1·36	1·21
13	11		1·56	1·co	1·21
14	11		1·00	1·36	1·69

Relative Areas of Star Discs in Photographs of a Region in Cygnus, by Henry and Roberts.

Star No.	Henry.	Roberts.	Star No.	Henry.	Roberts.
20	11·39	5·06	10	3·06	1·89
1	10·56	6·89	14	3·06	1·56
6	10·56	5·06	24	3·06	2·25
2	9·00	5·64	25	3·06	1·56
13	9·00	3·24	17	2·48	1·26
5	7·56	5·06	7	2·40	1·56
18	7·56	2·64	3	2·25	2·64
16	5·06	2·25	12	2·25	1·26
4	4·00	3·51	23	2·25	1·56
21	4·00	2·25	19	1·75	1·00
26	4·00	2·25	15	1·56	1·00
11	3·51	1·56	8	1·00	1·00
22	3·51	1·89			

Relative Areas of Star Discs in Photographs of the Cluster 35 *Messier Geminorum, by Henry and Roberts.*

Star No.	Henry.	Roberts.	Star No.	Henry.	Roberts.
4	9·00	2·8	18	2·25	1·80
15	7·56	3·36	2	2·25	1·36
12	5·47	2·25	13	2·00	1·56
24	5·06	2·51	3	1·80	1·36
23	4·70	2·25	6	1·80	1·36
19	4·34	2·80	17	1·80	1·56
11	4·00	2·25	9	1·36	1·36
7	3·36	1·80	14	1·36	1·36
16	3·36	2·00	10	1·17	1·36
5	2·80	1·80	20	1·17	1·36
1	2·80	1·56	8	1·00	1·00

Relative Areas of Star Discs in Photographs of the Nebula 1180 *H.G.C., by Henry and Roberts.*

Star No.	Henry.	Roberts.	Star No.	Henry.	Roberts.
17	58·8	9·90	18	2·80	1·65
1	28·44	6·61	9	2·25	1·65
12	25·00	7·40	15	2·25	1·65
5	21·80	6·61	6	1·80	1·00
8	11·11	5·20	10	1·80	1·30
4	4·00	3·00	11	1·80	1·30
7	2·80	2·50	2	1·36	1·15
13	2·80	2·50	3	1·00	1·00
14	2·80	2·00			

It will be at once remarked that the *order* of magnitude is the same in both the reflector and the refractor photographs, but the *relative* magnitudes to the eye as judged by the size of disc are widely different—that is, the scale is different.

In the Pleiades, stars from the 7th to the 11th magnitude, which in the refractor photographs show a range of area from 25 to 1, in reflector photographs range from only 4 to 1. In the other photographs the magnitudes have not been photometrically determined, but the relative areas present a similar difference.

The comparison of the star discs in the photograph of the nebula N.G.C. 1977 has one point of interest, in that the measured diameter of the brightest star is nearly the same in both, and the scale of enlargement is about the same; but the relation of the areas of the smaller stars is very different.

In all the reflector photographs it will be found that there is an *equalisation* of the magnitudes, and the conclusion is arrived at that differences of brightness which are perceptible to the eye in telescopic observation are equally perceptible in refractor photographs, but except between much wider limits are not so perceptible in those taken with a reflector.

In considering the cause of this great difference in photographs of stars by the two forms of instrument, it is extremely unfortunate that we possess so little information as to the quality of photographic star-discs produced by reflecting telescopes, and there is not much literature on the subject. I am not aware of any other results available but those of Dr. Common, Dr. Roberts, and von Gothard, all employing telescopes of the Newtonian construction.

The Bulletin of the International Permanent Committee contains a paper, by Dr. Scheiner, On the Application of Photography to the Determination of Stellar Magnitudes, in which he compares photographs taken by von Gothard's reflector with those obtained with a 5-inch refractor at Potsdam. I think this is the only paper published that at all deals with the question under discussion.

Though von Gothard's photographs are on a smaller scale, with images by no means round, the results Dr. Scheiner gives from measuring the diameters entirely confirms what I have said, that in photographs taken with a reflector the *scale* of magnitude differs from that with a refractor; a fact that is well known, and that for a given range of magnitude there is less variation in the size of the discs in the former case than in the latter.

The explanation of this difference is not a very simple matter, but I do not think it difficult to point out a possible cause of the anomaly, which detracts so seriously from the value of the photographs under discussion.

Dr. Scheiner in the paper cited above discusses some of the causes in the refracting telescope which affect the photographic image of a star, and points out that the progressive enlargement

of the discs with increased exposure cannot be due to the interference rings surrounding the star image. The explanation of this phenomenon may possibly be found in a lateral reflection of light from the particles of silver haloid, or to a chemical action between particles directly exposed to light and those in their vicinity.

The great advantage of a short-focus reflector for photographing nebulæ has been completely established by the remarkable results that Dr. Roberts has so successfully obtained. In photographing stars, however, the influence of the arms supporting the flat has never been thoroughly considered or investigated. All observers with reflectors of this construction know that the images of stars are never perfect, that there is always more or less of *flare* to the image, and though the seeing may be very good, the image on close examination is never a perfect one, but irregular and uneven. In bright stars the imperfection of the image is seen to be due to the six or eight rays radiating from them, caused by the arms of the flat. The same cause will operate with the fainter stars—less visibly to the eye, but revealed in a photograph of long exposure. The short focus is also less favourable for the production of perfect star images; and the adjustments generally of a reflector are of an extremely delicate nature. The phenomenon of interference rings has also been shown to be present in the reflector image, and this still further complicates the question.

It is, I think, to a combination of these defects that we must seek for a solution of the above anomaly. It seems probable, and I think demonstrable, that the Newtonian reflector photographs stars in their true relative brightness, *plus* a certain amount of flare in each case, due mainly to the scattering of light by the arms supporting the flat; in other words, the stars are photographed in their true relative brightness *plus a constant*, which would at once explain the difference of scale and the equalising of the magnitudes. It was most truly remarked the other day, by Sir Howard Grubb, that "in the photographic method the record of the observation is not that of any one moment; it is the aggregate of all the impressions made every second, and every part of a second, during the exposure. The photographic plate, unlike the eye, takes note of and records every position of the star image." The photographs under consideration faithfully record all the defects of the imperfect image formed by the Newtonian reflector, with the result that they do not present to the eye a true portrait of the object, so far as the relative brightness of the stars is concerned.

It would be a most interesting and instructive line of research to photograph stars with a reflector of the Herschelian construction. The baleful influence of the flat, with its adjustments and supports, would be eliminated, and the true value of a mirror for astronomical photography would be determined far more accurately than has yet been the case.

1894 *June* 7.

On the Formation of Photographic Star-Discs.

By H. F. Newall, M.A.

It is probably generally admitted that the formation of photographic star-discs is not yet understood. A telescope which ought theoretically to give a spurious disc, whose diameter is, let us say, 1″, gives in practice a photographic disc whose diameter increases with the brightness of the star and the exposure given to the plate, and may reach a value approaching or even exceeding 60″—a statement which is true not only of refractors but also of reflectors. This is a defect, and a very serious defect for some investigations; on the other hand, in some cases it is a positive advantage, and astronomers make the best of the peculiarity by basing estimations of star magnitudes upon it. It is difficult to form an idea as to how much labour and trouble in such an undertaking as the making of the Photographic Chart is saved by the existence of these expanding photographic discs. One may almost say that it has now come to be a distinct merit in an instrument that it should give expanding discs.

In applying photography to the determination of parallax it would clearly be an advantage to get more point-like images both of bright stars and of faint stars with a given exposure. Hence it would appear to be of considerable importance to advance, if possible, to a knowledge of the secret of the formation of expanding photographic discs, and I beg leave to lay before the Society an account of some experiments and measurements bearing on the subject.

The importance of a vigorous attack on the subject is obvious, inasmuch as there are many proposals to build large photographic telescopes. Let me instance the 18-inch photographic telescope suggested for the Cambridge Observatory, and the 26-inch photographic telescope for Greenwich. It is not quite clear that from such telescopes results may be expected proportionate to the dimensions and cost of such instruments, unless some departure is made from the existing mode of construction of the object-glass. A larger scale in the photograph, in which everything is equally magnified, not only separation of star-centres, but also disc diameters, would not bring much advantage.

One of the most notable points about a good photographic star-image is the definiteness of the boundary of the disc, whatever its diameter may be. In the case of a prolonged exposure the image of a bright star may readily come to have a diameter exceeding 1 millimetre on the photographic plate. Yet the distance (measured along the radius) in which the density of silver deposit changes from full value to zero is a very small fraction of the radius of the disc.

Scheiner has recently published an important paper, "[illegible]
P[illegible]

die Verbreitung der photographischen Sternscheibchen" (*Ast. Nach.* No. 3173, vol. cxxxiii. 1893, p. 73). He calls attention to the experiments made by Dr. Max Wolf, by which it has been proved that the growth of the photographic star-disc in long exposures cannot be attributed solely to diffusion of light within the sensitive film from the bright star-image formed on the film during the exposure.

In Wolf's experiments the sensitive plate was in part covered by an opaque meshwork, and was in this state exposed in the telescope to a region rich in stars; some star-images fell on uncovered film, others on the opaque bars, others on the edge of the bar, and it was seen that the extension of the discs occurred whether the central brightest part of the star-image fell on the bar or on the uncovered film. Dr. Wolf was good enough to show me the images two years ago, when I was in Heidelberg, and my recollection of the appearances may be conveyed by the figures given on Plate 10, fig. 1.

A second experiment of Dr. Wolf's consisted in brushing dust over a plate before it was exposed. After development it was clear that where a star-image had fallen on a particle of dust a shadow was cast, even though such shadow was close to the boundary of the disc. This shadow could only have been cast by light emanating from the object-glass.

Both experiments prove that the expansion of the disc is in the main due to the impact of light coming from the object-glass. Dr. Scheiner has made further experiments which prove that there is *some* extension due to radial diffusion of light within the film from the centre of the image, but that this extension is always relatively small.

In investigating the performance in photographic work of a large visual telescope, some account of which I had the honour of communicating to the Society at the last April meeting, I came across phenomena in the star-image which were obtained on various plates, and as they seem to throw light on the question, I proceed to describe them.

An enlargement of the mark made by *α Lyræ* on an ordinary photographic plate placed near the visual focus of the 25-inch visual refractor at Cambridge is shown in fig. 2 of Plate 10. The series of rings which are seen in this mark have been investigated with interesting results. The mark may be described as a circular spectrum whose red end is at the centre, and whose violet end fades into invisibility at the confines of the mark. The rings are the hydrogen absorption lines in this circular spectrum of *α Lyræ*.

The plate, when placed at the visual focus, is $31^{mm}\cdot2$ from the focus for H_δ light. Had the star emitted only H_δ light, the circle of diffusion on the plate would have had a diameter of $2^{mm}\cdot2$, and the light would not have been equally diffused over this circular mark; but for reasons not yet fully understood, the brightest part would be the outer annulus. The general effect would be similar to that shown in fig. 3, Plate 10. If the

exposure were so short that only the brightest part of the mark were impressed on the plate, there would be simply a bright ring about $2^{mm}\cdot2$ in diameter, and darkness within and without the ring.

If, on the other hand, the star emitted all kinds of light except H_δ light, and if light of each particular wave-length were collected into an annulus whose diameter was appropriate to the distance of the plate from the focus for the light of the wave-length considered, there would be contiguous bright annuli giving the appearance of regular illumination all over the mark with the exception of one dark annulus for the absent H_δ light.

The concentration of light into the outer ring of the diffraction pattern in any circle of diffusion is a well-known phenomenon, and excessive concentration is taken to be a proof of the existence of outstanding spherical aberration. I return to this point later (see page 522).

Marks similar to that illustrated in fig. 2 were obtained at various focus readings of the photographic plate, and careful measurements were made of the several rings in each mark. The measurements show that as the plate is moved uniformly outwards from the visual focus the rings contract uniformly. We may, in fact, regard each ring as the section of a right circular cone whose axis is the axis of the cone of rays from the object-glass : each ring has its own cone, its apex lying on the axis and being coincident with the focus for light of the wave-length corresponding with the marked absorption lines in the spectrum of the star. Stars of different spectral type give marks showing different rings. I deal with this point in a separate paragraph (see page 521).

I give in the following lines the results of measurements of the rings at different focus readings, taken from a plate exposed 1893 November 13, 6·30 ; *α Lyræ*. Three rings were measured in each mark.

Inner Ring.				*Middle Ring.*			*Outer Ring.*		
df. Focus reading of plate from arbitrary zero near visual focus.	D. Measured diameter of ring.	D × 14·0.* Deduced distance of apex from ; late.	(D × 14·0) + *df.* Deduced distance of apex from zero of focus readings.	D.	D × 14·0.	(D × 14·0) + *df.*	D.	D × 14·0.	(D × 14·0) + *df.*
mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
0·0	2·62	36 7	36·7	3·42	47·9	47·9	4·10	57·4	57·4
2·4	2·38	33·3	35·7	3·22	45·1	47·5	3·96	55·4	57 8
4·8	2·10	29·4	34·2†	2·94	41·2	46·0†	3·64	51 0	55·8†
7·2	2·04	28·6	35·8	2·82	39·5	46·7	3·66	51·2	58·4
9·6	1·94	27·2	36·8	2·74	38·4	48·0	3·40	47·6	57·2
12·0	1·74	24·4	36·4	2·60	36·4	48·4	3·22	45·1	57·1
14·4	1·54	22·1	36·6	2·40	36·6	48·0	2·98	41·7	56·1
16·8	(ring too faint to measure)			2·20	30·8	47·6	2·82	39·5	56 2
		Mean	36·0		Mean	47·5		Mean	57·0
			5·2			5·2			5·2
			30·8			42·3			51·8
			31·2			42·1			51·6

* The ratio focal length : aperture is 14·0.

† Something peculiar about readings in this third mark ; no reason can be given to warrant the rejection of them.

The mean of the deduced distances of the apex from the plate is given for each ring, and the smallness of the deviation from the mean in each column shows that the conclusion I reach is justifiable, namely, that each ring is the section of a conical shell in which there is little or no light.

The plate from which the above measurements were made was taken for a different purpose, and the actual position of the arbitrary zero from which the focus readings were measured was not recorded; but reasons given in a later paragraph (see page 522) lead me to ascribe the inner ring to the H_δ focus, the middle ring to the H_ϵ focus, and the outer ring to the K focus, each of these focuses being dark in consequence of the absorption of the light in the star's atmosphere.

If the visual focus were at $5^{mm}\cdot2$ from the arbitrary zero,* we should get the apex for the

	mm.	
inner ring at	30·8	from the visual focus
middle „	42·3	„ „
outer „	51·8	„ „

Now the distance of the

H_δ focus from the visual focus is	31·2	See *Monthly Notices*, present volume, page 373.
H_ϵ „ „ „	42·1	
K „ „ „	51·6	

For ease in comparison these numbers are put together below the "means" in the table given on the preceding page.

On another plate (1893 December 7, 6·30; *a Lyræ*, 10 minutes' exposure) which was exposed specially with a view to bring out, if possible, more rings, five rings were measured with the following results:

	Measured Diameter	Distance of Apex from plate = D × 14·0.	Distance of Apex from assumed visual focus = (D × 14·0) − 7·6.	Distance of focus for hydrogen lines from visual focus.
	mm.	mm.		
Innermost ring	1·64	22·96	15·36	H_γ 15·4
Inner ring	2·78	38·92	31·32	H_δ 31·2
Middle ring	3·64	50·96	43·26	H_ϵ 42·1
Outer ring	4·24	59·36	51·66	K 51·6
Outermost ring	4·68	65·52	57·92	H_ζ 61·2

The focus reading for this plate was, $2^{mm}\cdot4$, and if we again assume that $5^{mm}\cdot2$ is the position of the visual focus, then the distance of the apex of the cone, whose section is a ring, from the visual focus is less by $7^{mm}\cdot6$ than the number given in the

* In determining the diameter of a ring, the wire of the micrometer was set tangential to the *middle* of the annular dark ring at each end of a diameter. Hence, the deduced diameter is not exactly that of the circle of diffusion regarded from the standpoint of geometrical optics. The correction $5^{mm}\cdot2$ contains a correction for this.

column D × 14·0. These diminished distances should agree with the distances of the various hydrogen focuses from the visual focus if my hypothesis is correct. A comparison of the last two columns shows how far this is the case. I should add that the outermost ring was very difficult to measure, being extremely faint.

When a spectrum is photographed on an isochromatic plate, such as Edwards's, two maxima of photographic action are obvious —one in the yellow green, the other not far from the H_γ line—and further an obvious minimum is seen between the *b* lines and the H_β line : the plate is only slightly sensitive to the blue green. This insensitiveness to the blue green produces the same effect, so far as photographic action is concerned, as if the plate were as highly sensitive to the blue green as to other parts of the spectrum, and blue-green light were not allowed to fall on the plate.

If such a plate is set at some distance outside the visual focus of the telescope, and is exposed to the light of a star, such as *Procyon*, the mark produced on the plate has the appearance shown in fig. 4, Plate 10.

The outer bright ring is the annulus due to the yellow-green light, to which the plate is highly sensitive.

Just within this bright ring is a dark annulus due to the insensitiveness of the plate to blue-green light, and this is an effect which might be brought about on a uniformly sensitive plate by a star with a dark absorption line in the blue green.

Within the dark ring is a bright disc attributable to the superposed circles of diffusion due to blue and violet light.

Lastly, the central nucleus is mainly due to that light which is brought to a true focus on the plate.

The only way in which the mark produced by the same star on an ordinary plate (such as Wratten & Wainwright's) set at the same distance outside the visual focus differs from that produced on the isochromatic plate consists in the absence of the outer bright annulus. This in itself is strong evidence that the bright annulus is due to yellow-green light.

A series of marks has been got on an isochromatic plate set at various focus readings. Measurements were made of the diameter of the bright annulus, and it was found that the diameter of the bright annulus in any mark bore a constant ratio to the distance between the plate from the visual focus when that mark was produced. The bright annulus is, in fact, the section of a right circular cone whose apex is at the visual focus. Similarly, it was shown that the dark annulus is the section of a right circular cone whose apex falls between the visual focus and the focus for H_β light. It is not necessary here to give in full the measurements by which these facts were established. They were more precise than those given for the rings due to hydrogen absorption in *α Lyræ*, inasmuch as the visual focus was made the arbitrary zero for the focus readings of the plate. See fig. 5, Plate 10.

When the isochromatic plate is moved inside the visual focus, *i.e.*, nearer to the object-glass, it may be seen under certain circumstances that the bright annulus due to the yellow-green light is surrounded by a dark annulus due to the blue green; and that is to say, that, outside the visual focus, the bright annulus due to yellow-green light is outside the dark annulus due to the blue-green light, whereas inside the visual focus the dark annulus is outside the bright one.

A figure affords the readiest way of realising how this change takes place. See fig. 6, Plate 10.

In one mark which I have got on an isochromatic plate set $1\frac{1}{2}$ inch inside the visual focus, the bright and dark annuli due to these peculiarities in the sensitiveness of the plate are seen surrounded by the dark rings due to many of the absorption lines of hydrogen in the star *Procyon* which made the mark; it is possible to trace the rings due to H_β, H_γ, H_δ, and H_ϵ with certainty, and those due to K and H_ζ with some difficulty. See fig. 9, notably, *d*, *e*, *f*.

Fig. 7 shows on an enlarged scale the marks made by *Procyon* on an isochromatic plate exposed behind a dark yellow glass at various focus readings, the exposure being four minutes in each case.

a	*b*	*c*	*d*	*e*
$-1\frac{1}{2}$ in.	$-\frac{3}{4}$ in.	0	$+\frac{3}{4}$ in.	$+1\frac{1}{2}$ in.

The diameters of the bright annulus which I ascribe to the yellow light are

$2^{mm}\cdot54$	$1^{mm}\cdot36$	$^{mm}\cdot31$	$1^{mm}\cdot42$	$2^{mm}\cdot74$

I will not dwell on the difference between the measured diameters on the two sides, as I am not prepared to say that the middle exposure was made precisely at the visual focus.

But I hasten to point out that the bright centre in the marks outside the visual focus are due to the blue and violet light which, when condensed as it is on the plate placed in the midst of the focuses for these colours, is able to pass through the yellow glass in large enough quantities to affect the plate. I have exposed an ordinary (not isochromatic) plate (of about the same sensitiveness in the blue and violet as the isochromatic plate) behind the same dark yellow screen as was used in taking the marks figured above, and have found that enough blue and violet light gets through the screen to make marks as strong as the centres of the marks figured above, and measurement shows that the dimensions of the inner disc and nucleus are the same in the two cases.

Influence of the Spectroscopic Nature of a Star's Light on the appearance of the Rings in the Marks made by the Star.

The rings are not equally noticeable in the marks made on the plate by different stars.

In the mark of *α Cygni*, there is hardly a trace of a ring

The lines in the spectrum of this star are narrow, as is well known. The mark of *a Lyræ*, taken on the same plate on the same night, shows well-defined rings.

In the mark of *a Aurigæ*, two rings are marked. There are two broad absorption lines in the spectrum of this star, namely, H_ϵ and K. Measurement of the rings proves that the rings have diameters which coincide with those of the circles of aberration for light coming from the focuses of H_ϵ and K.

In the marks of *α Canis Majoris* and *β Tauri*, the set of rings seen are similar to those seen in *a Lyræ*. The hydrogen lines are marked in all these stars.

In the marks of *a Boötis*, traces of H_ϵ and K rings are seen only after considerably longer exposures than are needed to show them in *a Lyræ*. The marks of *a Lyræ* and *a Boötis* have been taken on one plate side by side, exposures of $\frac{1}{2}^m$, 2^m, 4^m, and 8^m being given to each star. Rings are visible in all the marks of *a Lyræ*, additional rings being added on the outer boundary with the longer exposures, but only the eight minutes' exposure for *a Boötis* shows the H_ϵ and K rings distinctly, the boundary being well defined in all exposures after the half minute, and the only effect of longer exposure being to increase the density of the image within the radius of the H_ϵ absorption ring. The well-known distribution of light in the spectra of these stars would account for the observed differences. A comparison of the diameters of the rings in *a Boötis* and *α Lyræ* leads to the identification of the rings in *a Lyræ* referred to on p. 519.

Spherical Aberration.

The whole explanation which I suggest of the peculiarities observed in the marks depends on the concentration of light in the outer part of the circle of diffusion for light of any wave-length. As it appeared that there were signs of *excessive* concentration which might be attributed to spherical aberration, I exposed a plate to one and the same star, and used different apertures.

Having found that the most marked ring was that seen on isochromatic plates, I used such a plate for this purpose, and found that the ring was equally well developed whether the aperture used was 24 inches, 18 inches, 12 inches, or 6 inches.

The plate was set at a fixed distance ($1\frac{1}{8}$ inch) outside the visual focus, and the marks produced with different apertures were obtained side by side on the plate. The rings were measured, and the proportionality of diameter of the outer ring to the aperture was confirmed.

	12-inch Aperture.	18-inch Aperture.	24-inch Aperture.
Diameter	$1^{mm}\cdot129$	$1^{mm}\cdot645$	$2^{mm}\cdot218$
	$26''\cdot3$	$38''\cdot4$	$51''\cdot7$
$\frac{\text{Diameter}}{\text{Aperture}}$	$\frac{1\cdot13}{12}=\cdot0927$	$\frac{1\cdot65}{18}=\cdot0914$	$\frac{2\cdot22}{24}=\cdot0924.$

Fig. 8 is an enlargement of the marks taken on one plate with the three larger apertures. The marks for the 12-inch and 6-inch apertures were taken on a separate plate, but the ring is somewhat difficult to print when the diameter is so small.

Distribution of Light in Circle of Diffusion for Light of given Wave-length.

In order to study the distribution of light in the circle of diffusion for light of any given wave-length resort must be had to artifices.

First, a pinhole backed by a sodium flame was set up at a distance, and was observed with a 4¼ refractor by Cooke of most excellent qualities. The concentration of light in the outer annulus of the circle of diffusion was very marked.

What is true for one telescope, however, is by no means necessarily true for another, and the above observation is recorded merely to show that a strong concentration of light in the outer annulus is present in the case of a telescope, which shows no sign of spherical aberration in the ordinary tests.

For the 25-inch refractor I have investigated the matter by putting an isochromatic plate at a focus-reading 1½ inch within the visual focus behind a dark yellow glass. In this way I attempted to separate the effects due to yellow-green light from those due to blue and violet, for the yellow glass cuts out the blue and violet much more strongly than the yellow and green; further, the blue and violet light is very much more diffused on the plate because the focuses are more than twice as far from the plate; and, lastly, the blue and violet focuses are comparatively sparsely distributed along the axis, whilst the yellow-green focuses are condensed into a very short length of axis. Fig. 9, *a*, *b*, *c*, shows the mark obtained in this way when the plate is exposed to the action of the light coming from the star Procyon. Further, some idea of the separation of the effects of the blue and yellow lights is gained by a study of fig. 9, Plate 10 (see explanation of the figures at the end of the paper).

There seems to be established by these experiments the fact of the existence of an important concentration of light in the boundary of the circle of diffusion for light of any wave-length. As to the physical reason for this annular concentration I am not at present prepared to speak. But Lommel's work gives one grounds for thinking that it may be a straightforward result in the theory of diffraction through a circular aperture. I have not found the energy or time as yet to grapple with an extension of Lommel's work, but I hope that someone more versed in the use of Bessel's functions than I can claim to be may be induced to attack the problem. But we must admit that the annular concentration exists, whatever the cause of it may be.

Now *assume* that in the "photographic" telescope the correction of chromatic aberration is not perfect. Then we see that with

prolonged exposures the effect of the focuses remote from the plate will make itself felt in the addition of rings to the disc already formed by the nearer focuses.

In this way the well-known facts relating to the differences between visual and photographic magnitudes receive a simple explanation. A star which has a strong ultra-violet spectrum produces a disc whose diameter is quickly increased by the addition of ultra-violet rings.

The absence or faintness of light at the centre of the larger circles of diffusion suggests a simple explanation for a feature which has always surprised me—namely, that the centres are not more quickly solarised.

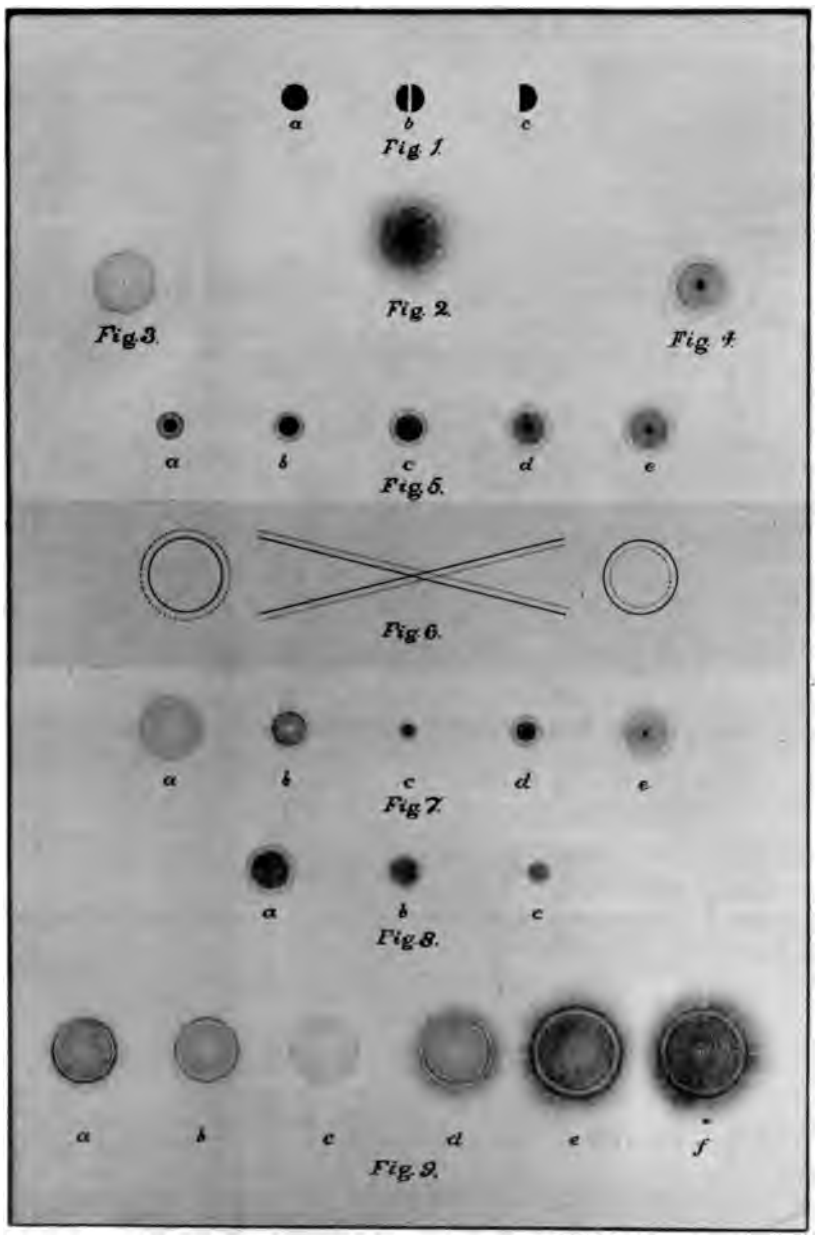
In order to gain some idea as to the growth of a monochromatic image on a photographic plate with increasing exposures, I have used the objective prism in front of the object-glass to throw a spectrum of *Polaris* on a Wratten & Wainwright plate. The clock was rated and the telescope guided so as to avoid any trail of the spectrum on the plate. On one plate I made four exposures—2 min., 4 min., 10 min., and 65 min.—and measurements at the same part of the spectrum in all the four exposures show that the growth in width is very small.

	mm.		"
In the 2 min. exposure the width was	0·077	or	1·79
„ 4 min. „ „	·119	„	2·77
„ 10 min. „ „	·147	„	3·42
„ 65 min. „ „	·170	„	3·96

Atmospheric tremor produces sudden movements of a star in the field of view of the telescope, and these often amount to as much as 2″. In trails of stars across a fixed plate in a stationary telescope I have measured the deviations in declination from the straight line described by the star: this was done with a view of estimating how much of the width of these spectra of *Polaris* is attributable to similar movements on the plate. Deviations amounting to 2″ have been measured in trails taken on not very bad nights. On a night in which the seeing was described as "very good $\frac{4}{5}$," the deviation measured was 1″·5. On a night when the seeing was described as "very bad $\frac{1}{5}$," the deviation measured was 6″. The total amplitude was double these numbers; and it appears, therefore, that the movement of the image on the plate will account for a great part of the width of the spectrum.

It must be remembered, however, that in dealing with a small part of the spectrum we deal with a very small part of the light of *Polaris*, so that these four images of the spectrum should be compared with the images of very faint stars.

I may refer to the case of a star-mark which I have obtained on an isochromatic plate. The plate was so set that the ring due to the yellow-green light was larger than any that could be formed by any other light. Measurement showed that the in-


a
b
c
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
a
b
c
d
e
Fig. 5.
Fig. 6.
a
b
c
d
e
Fig. 7.
a
b
c
Fig. 8.
a
b
c
d
e
f
Fig. 9.

crease in diameter when the exposure was prolonged was very small. Some similar measurements are given on p. 378 of the present volume.

I do not hesitate to think that the cases of reflectors and refractors must be dealt with separately. I have been led to the view that chromatic aberration is the prime cause of expansion of photographic star discs obtained with refractors. It appears doubtful whether a perfect correction *can* be obtained with only two lenses in the object-glass. There remains the case of the reflector still to be explained.

The success of Dr. Hastings's triple objectives was so encouraging that one rejoices that Messrs. Cooke & Son have been able to secure large discs of special glass, which Mr. Taylor has found on calculation to promise excellent colour corrections, and it is to be hoped that in the attempt to produce an object-glass which will serve equally well for visual and photographic work the optician does not set on himself a constraint which will stand in the way of the best possible results in either one or the other line.

Explanation of Figures in Plate.

With the exception of figs. 1 and 6, the figures are enlargements (about two-and-a-half-fold in all cases). The figures are *negatives*. The photographic reproduction does not do justice to the admirable pencil drawings made by Mr. Wesley from the original negatives.

Fig. 1.—To illustrate Dr. M. Wolf's experiment.

a. Star image fell on the uncovered film.	*b.* Centre of image fell on centre of bar.	*c.* Centre of image fell on edge of bar.

Fig. 2.—Mark produced by α *Lyræ* on an ordinary plate set at the visual focus: exposure, thirty seconds. Radial marks due to diffraction. Concentric rings are those referred to in the paper.

Fig. 3.—To give an idea of the distribution of light in a circle of diffusion for light of given wave length.

Fig. 4.—Mark on an isochromatic plate set 1½ inch outside the visual focus. Outer ring due to yellow-green light.

Fig. 5.—Set of marks on an isochromatic plate set at different focus-readings outside the visual focus: exposure, thirty seconds in each case. Procyon.

a. $\frac{8}{16}$ in. *b.* $\frac{3}{4}$ in. *c.* $\frac{12}{16}$ in. *d.* $1\frac{1}{8}$ in. *e.* $1\frac{5}{16}$ in.

Fig. 6.—To illustrate change in position of rings inside and outside the focus.

Fig. 7.—Marks on an isochromatic plate set behind a dark yellow screen at various focus-readings: exposure, four minutes in each case.

a. $-1\frac{1}{2}$ in. *b.* $-\frac{1}{4}$ in. *c.* visual. *d.* $+\frac{3}{4}$ in. *e.* $+1\frac{1}{2}$ in.

Fig. 8.—Three marks on an isochromatic plate kept at a fixed focus-reading: exposures with different apertures.

a. 24 inches aperture. *b*. 18 inches aperture. *c*. 12 inches aperture.

Fig. 9.—Marks made by Procyon on plate exposed at $1\frac{1}{2}$ inch within the visual focus.

	a	*b*	*c*	*d*	*e*	*f*
Exposure	8^m	4^m	1^m	1^m	4^m	8^m
	with dark yellow screen interposed.			without screen.		

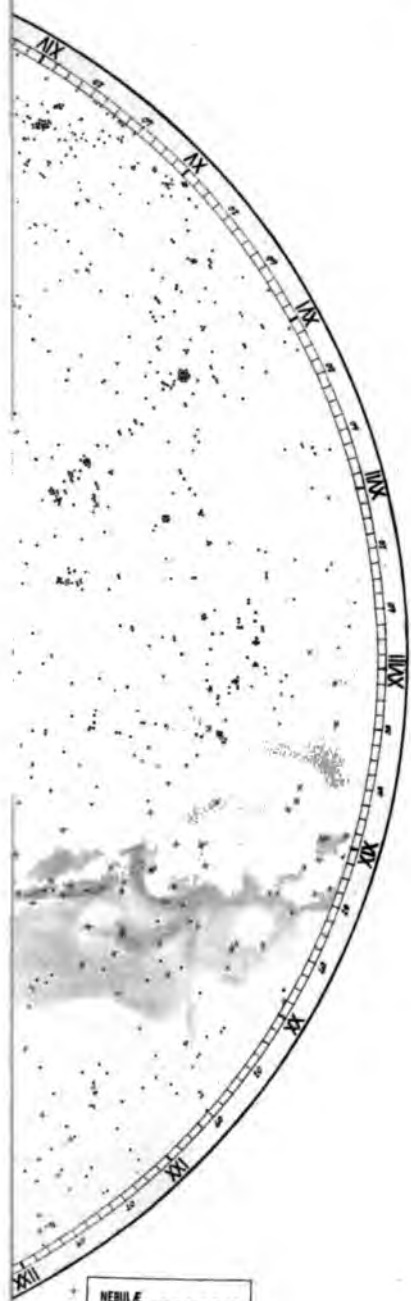
On Two Distribution Maps of the Nebulæ and Clusters in Dr. Dreyer's Catalogue of 1888. By Sidney Waters.

In 1873 I had the honour to lay before the Society in two maps a graphical representation of the distribution of the nebulæ and clusters of the General Catalogue (Sir John Herschel's Catalogue of 1864). Since then the New General Catalogue (Dr. Dreyer's Catalogue) has been published; and whereas the earlier Catalogue contained the positions and descriptions of 5,079 objects, more than half as many again—*i.e.*, 7,840—are enumerated in the later one. The northern section of the Milky Way in my original maps was copied from Heis, and the southern section from Sir John Herschel's drawing; but there are now available the beautiful drawings of Dr. Boeddicker, and also those of Dr. Gould in the *Uranometria Argentina*.

It appeared to me under these circumstances that fresh maps constructed under the improved conditions would be interesting, and in the charts which I now beg to present to the Society I have laid down upon the same projection as before all the objects contained in the New General Catalogue. I have added a copy of Dr. Boeddicker's Milky Way, for which I am indebted to Mr. Wesley's excellent engraving for the northern heavens, and a copy of the Milky Way as it appears in the *Uranometria Argentina* for the southern heavens.*

The projection is that described by Sir John Herschel on p. 134 of the *Results of Astronomical Observations at the Cape of Good Hope*, and by its means equal areas in the heavens are represented by equal areas on the charts. The defect of this projection is the distortion occasioned as the Equator is approached, but for distribution maps it is practically the only projection that will satisfy the desirable condition of equal areas. The positions of all objects are laid down as accurately as possible, but the exceeding nearness of many of them to one another has made it impossible in such cases to place them in precisely their true positions,

* I have to thank Mr. Wesley for the great amount of trouble that he has taken to secure a satisfactory reproduction of the charts, and in particular for very skilfully lithographing the Milky Way upon the reduced scale.



W. H. Wesley lith.

West, Newman

and at the same time to render them as separate objects. In the case of the Magellanic clouds the crowding has resulted in these extraordinary aggregations being made to cover a larger area upon the chart than should be the case, and in the great nebulous region of Virgo and in other places where the crowding is exceedingly great small displacements of position occur in consequence. In looking at the drawings of the Milky Way in the two hemispheres, it will be remembered that the projection is altered, and that the originals have been produced by observers under different conditions of climate, power of vision, &c., and that Dr. Boeddicker's work was the result of years of patient observation, resulting in a record of an astonishing wealth of detail.

I have designed the charts with two objects. First, as a study of the distribution of the clusters and nebulæ, and, secondly, as a possible guide to astronomers who are engaged upon observations of the nebulæ photographically and otherwise.

With regard to the clusters, which are marked with a red cross, it is striking to note the fidelity with which they follow not only the main track of the Milky Way, but also its convolutions and streams. They appear in many parts to seek out the denser regions and to avoid with an equal persistence the dark spaces. It appears to me that if further confirmation were required in favour of the view that the clusters are immersed in and a part of the galaxy itself, these maps supply it, for it is impossible for such a scheme of distribution to have arisen through chance scattering.

I have divided the nebulæ into two classes, separating those described in the Catalogue as resolvable from the rest. The resolvable nebulæ are marked as red dots, and the irresolvable nebulæ as black dots. This was done in the original maps, and I have therefore kept up the distinction, although I am aware that this difference is inclined to disappear under recent research. A proportionate scattering of resolvable nebulæ follow the others throughout the charts, showing that they are probably intermixed, and that the resolvability of many of them must not necessarily be regarded as a criterion of their distance. The remarkable avoidance of the nebulæ of the galaxy, although in some points reaching up to and encroaching upon its edges, is equally significant with the coincidence of the clusters with its main track, and in this respect there is nothing to alter the conclusions which have been previously drawn from this circumstance. The additional nebulæ in the new maps are by no means uniformly distributed. Among the alterations which attract attention in the northern heavens is a considerable accession of numbers in the regions of *Draco* and *Corona Borealis* and *Serpens*, and there is an addition in the remarkable extension of the nebular system which runs up from *Pegasus* through *Andromeda* to *Perseus* upon the border of the Milky Way. There is also an increase in the neighbourhoods of *Cancer* and *Lynx*, while

in the southern hemisphere the increase of numbers is not so great as in the northern, nor is it very noticeable in any particular quarter; and I commend this fact to the attention of the southern observatories, in the hope that more attention may be given to the search for these objects.

There are two points that have occurred to me continually while engaged upon the maps: the exceeding nearness to one another of very many of the nebulæ suggests the probability of physical connection in many instances analogous to that of double stars, and I recommend it as a hopeful field of research whether orbital motions can be detected by the spectroscope or by photography. I have also again and again noticed configurations which remind one of groups of stars having a common proper motion; and the second suggestion I would make is the likelihood of a good result from an examination for proper motion.

With regard to the second object that I had in view in constructing the maps, I have little to say except that I hope they may serve to indicate, though roughly no doubt, the parts of the heavens likely to repay research, inasmuch as a graphical representation must necessarily have some advantage over a catalogue for this purpose.

Note on B.A.C. 5,255 = *Brisbane* 5,525. By A. M. W. Downing, M.A., D.Sc.

My attention has been called to No. 5,255 of the British Association Catalogue of Stars, by Dr. E. Lamp, who informs me that, on looking for the occultation predicted in the *Nautical Almanac* for March 25 last, he was unable to find any star in the assigned place, and that on several subsequent occasions he was equally unsuccessful. The place given in the B.A.C. depends on one observation made at Paramatta, and Dr. Lamp suggests that this observation may really have been one of the neighbouring star 3 *Scorpii*, with an error of 10′ in the recorded declination, as well as an error in the R.A. The reference to Taylor V., 2,873, given in the B.A.C., is misleading, as Taylor merely gives the approximate position taken from Brisbane's Catalogue, and, as a reference to his MSS. shows, on reducing his attempt to observe this supposed star, found that he had really observed 2 *Scorpii*. A note to the recorded position of the latter star in the Cape Catalogue for 1880 says: "No seventh magnitude star was visible on 1878 June 12 nearer R.A. $15^h\ 47^m$ and N.P.D. 115° 3′, which is the place of Brisbane 5,525." The Cordoba *Durchmusterung* gives no star in this place, although there is a 9·8 mag. star exactly 1^m later in R.A., and of the same declination. Lastly, Mr. Crommelin kindly informs me that he has looked for the supposed star on two separate occasions, but has been unable

to see any object in the assigned place. It may safely be concluded, therefore, that no star as bright as 6–7 mag. exists in the place given for B.A.C. 5,255, and the entry should, accordingly, be struck out wherever it occurs in the Occultation Section of successive *Nautical Almanacs*, up to and including that for the year 1895.

Nautical Almanac Office:
1894 *June* 5.

On the Orbit of OΣ 82. By J. E. Gore.

The angular motion of this binary pair from 1845·96 to 1892·00 has been only 82°; but I find that the motion has been round the apoastron end of the ellipse, and that a considerable arc of the apparent orbit has been described between the above dates. I have computed the orbit by the Glasenapp-Kowalsky method, and find the following provisional elements:

Elements of OΣ 82.

P = 90·54 years.	Ω = 21° 32′
T = 1827·36	λ = 339° 32′ (or 20° 28′)
e = 0·335	a = 0″·80
i = 52° 7′	μ = −3°·976

The value of λ, 339° 32′, is measured in the direction of the position angles, and 20° 28′ in the direction of the orbital motion, which is retrograde.

The following is a comparison between the measures used in calculating the orbit and the positions computed from the above elements.

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1845·96	Mädler	231°·7	234°·96	−3°·26	0″·9	0″·68	+0″·22
1848·66	O. Struve	230·4	227·05	+3·35	1·04	0·75	+0·29
1866·73	Dembowski	195·9	196·6	−0·7	0·94	1·05	−0·11
1879·695	Burnham	179·4	177·9	+1·5	0·54	0·93	−0·39
1891·01	Hall	151·56	151·98	−0·42	0·79	0·68	+0·11
1892·00	Burnham	149·3	148·67	+0·63	0·62	0·65	−0·03

Assuming that the mass of the system is equal to the mass of the Sun, the "hypothetical parallax" would be

$$p=\frac{a}{P^{\frac{2}{3}}}=0''\cdot04.$$

The magnitudes of the components are 8·0 and 8·7, and the approximate position of the star for 1880·0 is

R.A. $4^h\ 15^m\ 55^s$
Decl. +14° 46′.

Note on the Variable Star U Orionis.

By Lieut.-Col. E. E. Markwick.

Up to date of writing, observations of this star have been secured at Gibraltar this season on thirty-three nights, commencing January 7 and ending April 3. They were made, as in former years, with a binocular magnifying five times. I have never been able in past years to get so many observations and so close together, about the time of maximum. The maximum, therefore, so far as my own observations go, can, I think, be allocated with considerable confidence to 1894 February 8. I base this determination on three observations, as follows :

Feb. 6	$6^m{\cdot}07$	In the Harvard Scale, as nearly as possible.
9	$6^m{\cdot}27$	
10	$6^m{\cdot}07$	

On no other occasion was the star so bright as on February 6 and 10 ; hence the mean gives fairly enough the date of maximum—viz. February 8.

A maximum was observed by me about 1892 January 23 (see p. 604, vol. lii.). From this date to that of maximum in 1894 there are 747 days. As this corresponds to two periods, it gives as the mean period for those two years 373·5 days. This coincides practically with the period found by Gore on p. 518, vol. l., viz. 373·47 days.

Also, if we take the period elapsed from 1886 December 12 (the first well-determined maximum) to 1894 February 8, we get 2,615 days, corresponding to seven complete periods. This gives as a mean period 373·57 days.

It may therefore be taken that, so far as our observations go at present, we cannot much better the 373·47 days' period for U *Orionis*.

The difference between observation and computation is shown in the following table. The first column (C_1) gives the dates of maxima in the years named, based on Dr. Chandler's period of 371 days ; the second (C_2) the same on Mr. Gore's period of 373·47 days. The third column (O) gives the observed maxima, which are the means of all those published ones I have been able to collect—viz. by Gore, Sawyer, Yendell, Parkhurst, Dunér, and Markwick. There are only two determinations for 1893, and they have been kindly furnished to me by Mr. Gore. They are by himself and Mr. Corder, and both give February 4 a date of maximum.

It will be seen that the residuals with the 371 day period come out large and gradually increase, while those of the 373·47 day period are much smaller.

Computed Maximum. 371 Days (C_1).	373·47 Days (C_2).	Observed Maximum (O).	O−C_1 Days.	O−C_2 Days.
1886 Dec. 13	Dec. 12	Dec. 12	− 1	0
1887 Dec. 19	Dec. 20	Dec. 20	+ 1	0
1888 Dec. 24	Dec. 27	Dec. 29	+ 5	+2
1889 Dec. 30	Jan. 5	Jan. 9	+10	+4
1891 Jan. 5	Jan. 13	Jan. 19	+14	+6
1892 Jan. 11	Jan. 22	Jan. 29	+18	+7
1893 Jan. 16	Jan. 29	Feb. 4	+19	+6
1894 Jan. 22	Feb. 7	Feb. 8	+17	+1

There seem to be indications of an inequality in the period from both series of observations. Dr. Chandler, in his elaborate *Second Catalogue of Variable Stars*, notes "periodic inequality" against this star, although the terms have not yet been determined. He points out that inequalities in the variation of long-period variables are in general periodic, running through cycles of fifty or sixty periods on the average, sometimes of only twenty or thirty periods. It is hence pretty evident that we shall require a series of observations of this star extending over a considerable number of years before the period can be properly thrashed out.

I have prepared curves showing the variation in brightness for six seasons, dealing with it when higher than the 9th magnitude. They all show a pretty rapid rise to maximum, and a comparatively gradual declension subsequently. Also curious small fluctuations of light at times, especially when close to the maximum. In fact, the light curve bears a remarkable similarity to that of *Mira Ceti*, except that the rise to maximum of the latter star does not seem quite so sharp.

Gibraltar:
1894 *April* 16.

On the Semi-Annual Variation of Meteors.

By George C. Bompas.

(*Communicated by A. Cowper Ranyard.*)

In 1857 I addressed a paper to the Royal Astronomical Society on the horary variation of shooting stars (*Monthly Notices*, vol. xvii. p. 148).

According to the observations of M. Coulvier Gravier (*Recherches sur les Etoiles Filantes*, Paris, 1845; *Recherches sur les Météores*, Paris, 1859) and of other astronomers, the

average number of shooting stars seen increases from the evening to the morning hours.

This increase was explained in the paper to be due to the rotation of the Earth, and to the fact that the front of the Earth in her orbital motion would encounter more shooting stars than the back, as the front of a man's hat who runs through rain will get wetter than the back, and this in proportion to his speed.

At 6 P.M. the spectator stands at the back of the Earth, and looks back on the track already traversed. The Earth's rotation carries him round hour by hour till at midnight he enters the front hemisphere, and is again carried round until at about 6 A.M. he reaches the foremost meridian of the Earth in her motion along her orbit. To this chiefly is due the variation in the number of meteors from hour to hour.

The results of this paper were in the same year brought before the British Association by the Rev. Baden-Powell (*Report on Luminous Meteors*, 1857, p. 181).

In 1864 a paper by Professor Alex. S. Herschel, "On the State of Meteoric Science," was read to the Royal Astronomical Society (*Monthly Notices*, vol. xxiv. p. 133).

Professor Herschel's paper dealt with the semi-annual variation of meteors. "It is a saying of Arago," he wrote, "founded upon observation and confirmed by constant experience in later years, that the Earth encounters more shooting stars in going from aphelion to perihelion than in going from perihelion to aphelion."

The observations of Dr. Schmidt were cited, extending over eight years (1842 to 1850), and giving an average of 400 for the last six months, and only seventy for the first six months.

The table given, being founded on the total number of meteors observed in each month, requires correction by the number of days of observation, also given by Dr. Schmidt. When so corrected the proportion of meteors visible in the different months, according to his observations, appear to be as follows :

TABLE I.

Schmidt, 1842–1850.

Jan.	2·4	July	4·5
Feb.	1·2	Aug.	11·7
March	1·8	Sept.	3·1
April	1·8	Oct.	3·7
May	1·3	Nov.	5·3
June	1·7	Dec.	3·6
	10·2		31·9

the number in the second half-year being about three times that of the first half-year.

Professor Herschel suggested that this semi-annual variation was probably due to the planetary motion of the Earth, which might be expected to cause a season of frequency of meteors *in all latitudes* three months later than the summer season of the Sun. The northern hemisphere being in front of the Earth from June to December should encounter a larger number of meteors than between January and June, while in the southern hemisphere the season of frequency should be reversed.

Professor Pritchard discussed and adopted this explanation, which he observed depended on a similar principle to that of the horary variation; but pointed out that this theory would be tested by the result of observations in the southern hemisphere, where the same cause should make a corresponding but contrary variation, since the greater number of meteors should in the southern hemisphere appear in the *first* half of the year, when the southern hemisphere is in front of the Earth's orbital motion.

Professor Schiaparelli, in his treatise on meteors (abstracted in the British Association *Report on Luminous Meteors*, 1868, p. 408), adopts the same explanation of the semi-annual variation, and illustrates it by "supposing a meteoric sun or central radiant point of shooting stars to be situate at the apex of the Earth's way, whose rising and setting produce a meteoric morning and evening, and its culmination a meteoric noon and night, six hours before the corresponding change of the Sun—a meteoric spring and autumn, summer and winter, are a consequence of the varying declination (or meridian altitude) of the same meteoric sun, and accordingly follow three months after the corresponding tropical seasons of the year."

The horary and semi-annual variation of meteors have been recently fully discussed in the same sense by Professor Norman Lockyer in his *Meteoric Hypothesis*, chap. xii. p. 125.

The fact of the semi-annual variation is confirmed by many observers.

M. Coulvier Gravier, in his first work (1845), p. 172, gives the mean horary number of meteors for midnight as 3·4 in the first six months, and 8 in the second six months of the year, the latter figure being about two and a half times greater than the former, this average being deduced from the following table of his observations for the years 1841 to 1845:

TABLE II.

Coulvier Gravier, 1841–1845.

	1841.	1842.	1843.	1844.	1845.	Mean Number.
Jan.	...	5·6	3·4	3·3	3·7	3·6
Feb.	...	3·5	2·2	4·0	3·8	3·6
Mar.	...	2·3	3·4	2·6	...	2·7
Apr.	...	3·9	5·1	3·4	...	3·7
May	...	2·7	5·0	2·1	...	3·8
June	...	3·7	2·0	3·3	...	3·2
July	14·7	4·0	3·7	8·1	...	7·0
Aug.	7·0	11·9	9·4	5·4	...	8·5
Sept.	7·8	10·1	5·1	5·2	...	6·8
Oct.	5·6	9·0	3·7	11·4	...	9·1
Nov.	5·2	11·3	5·4	10·7	...	9·5
Dec.	6·6	8·5	10·0	5·4	...	7·2

In his second book, at p. 218, he gives the figures more exactly from twelve years' observation (1846 to 1857 inclusive), corrected for a clear sky, as 5·2 for the first half-year and 13·6 for the second half-year, with the same result of two and a half times the number for the first half-year. He also gives the horary variation for the first and second half-years separately as follows:

TABLE III.

Coulvier Gravier, 1846–1857.

	First Half-year.	Second Half-year.	Mean Number.
5 to 6 P.M.	8·5	7·0	7·2
6 „ 7 „	3·1	6·5	6·5
7 „ 8 „	3·4	8·5	7·0
8 „ 9 „	2·7	8·4	6·3
9 „ 10 „	3·2	11·0	7·9
10 „ 11 „	3·1	12·1	8·0
11 „ 12 „	4·1	13·3	9·5
12 „ 1 A.M.	5·2	14·5	10·7
1 „ 2 „	6·6	17·0	13·1
2 „ 3 „	8·1	20·4	16·8
3 „ 4 „	6·7	18·7	15·6
4 „ 5 „	6·2	18·4	13·8
5 „ 6 „	6·8	18·4	13·7
6 „ 7 „	6·1	17·2	13·0

This table shows also that the horary variation is more rapid in the second half of the year than in the first, being about twice in the first half-year against an increase of three times in the second half-year. It also shows that the maximum is in each half-year not at 6 A.M., but between 2 and 3 A.M., and therefore that the path of the meteor is not directly opposed to that of the Earth, but is in each half-year drawn in towards the Sun.

Mr. Denning gives the following table of the horary numbers of meteors in the several months of the year as the result of his own observations, making the numbers in the second half-year nearly double those in the first half-year. He also found the maximum to be between 2 and 3 A.M. (*Monthly Notices*, vol. l. p. 410.) In his table the Perseids are omitted from the computation.

TABLE IV.

Denning.

Jan.	6·5	July	11·3
Feb.	4·9	Aug.	11·3*
Mar.	6·6	Sept.	10·3
Apr.	6·6	Oct.	11·8
May	5·2	Nov.	11·3
June	4·9	Dec.	8·9
	34·7		64·9

There can be no doubt that the change in the position of the Earth's axis relatively to her motion must, as pointed out by Professor Herschel, tend to increase the number of shooting stars seen in the second half of the year in the northern hemisphere; but this cause has always appeared to me insufficient to account for the very large increase observed—viz. from two to three times the number observed in the first half of the year. This cause, so far as it has operation, depends upon precisely the same principle as the horary variation—viz. the change of the observer's position upon the surface of the globe relatively to the point towards which the Earth is moving.

The horary variation, which is also an increase of about two and a half times, shows that a change in the observer's position of about 180° in longitude is required to increase the horary number two and a half times. How can a change in the distance of the observer from the ecliptic, which at its maximum in passing from the autumnal to the vernal equinox amounts to only 47°, produce, not only at the equinoxes but throughout the half-year, an effect equal to a change of longitude of 180°?

The observations of Dr. Neumayer at the Melbourne Observatory for the years 1858 to 1863 appear sufficiently to

* Perseids omitted.

show that the change of position of the Earth's axis is not the efficient cause of the semi-annual variation of meteors, since this variation in the southern hemisphere is not in fact reversed, but follows the same law as in the northern, the hourly number of meteors seen in the second half of the year exceeding the number seen in the first half-year.

In Dr. Neumayer's *Report of Meteorological Observations at the Flagstaff Observatory, Melbourne, for the Years* 1858–1863, vol. iii. p. 141, the monthly horary numbers of meteors are given from observations of upwards of 2,000 meteors as follows :

TABLE V.

Neumayer, 1858–1863.

Jan.	2·2	July	3·2
Feb.	1·8	Aug.	3·2
Mar.	1·6	Sept.	2·8
Apr.	1·4	Oct.	3·0
May	2·0	Nov.	2·2
June	3·0	Dec.	2·9
	12·0		17·3

This makes the average horary number for the first half-year 2, and for the second half-year 2·9, the numbers for the second half-year being nearly 50 per cent. greater than for the first half-year.

The small numbers given for each hour show that these observations are not very complete. A statement in vol. ii. of Dr. Neumayer's reports shows that the number of hours of observation averaged only seventeen per month. The horary number given cannot, therefore, be considered exact.

The smaller increase recorded in the Melbourne Observatory may be partly accounted for by the fact that the numbers are not corrected with reference to the state of the sky. Dr. Neumayer notes particularly that in the month of November the weather was so unfavourable that it was impossible to determine in a reliable manner whether the November star shower was visible. A correction for the state of the sky might therefore considerably increase the numbers for the second half of the year.

Some difference will be due also to the alteration in the position of the Earth's axis, as already shown, which in the southern hemisphere would cause a deduction from any increase in the second half-year due to a cause common to both hemispheres.

The Melbourne observations are, however, sufficient to prove that the semi-annual variation of meteors follows the same law of an increase in the second half-year in the southern as in the northern hemisphere. It must, therefore, have some other or

further cause than that hitherto assigned—namely, the change of position of the Earth's axis.

A probable cause of the semi-annual variation of meteors may be found in the cosmical motion of the solar system, which renders the absolute motion of the Earth swifter in the first half of the year, while passing to aphelion, than in the second half of the year, while passing to perihelion, and would tend, therefore, to cause a semi-annual variation in the number of meteors encountered.

If meteors were at rest in space, and were encountered by the solar system, there would be a semi-annual variation contrary to that observed, the larger number of meteors being encountered by the Earth in the first half of the year, when her motion is swiftest.

If, however, the majority of meteors are assumed to have a proper motion, in a direction similar to but swifter than that of the Sun, the conditions would be reversed, and the larger number of meteors would be seen in the second half of the year, when the relative motion of meteors and the Earth would be greatest, consisting then of the sum of their velocities when meeting one another, instead of the difference of those velocities, as in the first half of the year.

If, for example, the motion of the Sun is assumed at 10 miles per second, and that of the meteors as equal to the Earth's orbital motion, say 18 miles per second, then at the vernal equinox the Earth would overtake the meteors with a velocity of $18 + 10 - 18 = 10$ miles per second, while at the autumnal equinox the Earth would meet the meteors with a relative velocity of $18 - 10 + 18 = 26$ miles per second.

Such a proper motion of meteors cannot, however, generally exceed the absolute motion of the Earth in the first half of the year, otherwise meteors would then overtake the Earth, and the horary variation would be reversed, the larger number of meteors being encountered in the evening hours.

If the semi-annual variation of meteors is due to the cosmical motion of the solar system, we must attribute to meteors an independent cosmical motion, and a cosmical origin.

The cosmical origin of meteors may with some probability be inferred from their number, if, as has been estimated, 20,000,000, or, if telescopic meteors are included, 400,000,000, are daily consumed in our atmosphere, besides the larger numbers absorbed by the other planets and by the Sun; yet the horary number shows no diminution.

That the relative motion of meteors and the Earth is in fact greater in the second half of the year may be inferred from M. Coulvier Gravier's observations (Table III.), which show that the horary variation of meteors is more rapid in the second half of the year.

If a proper motion of meteors may be assumed—and motion, not rest, is the law of the universe—the profusion of meteors

between longitude 0° and 60°, as observed by Mr. Denning, may show that the direction of their motion generally follows that of the Sun, and is drawn in towards the Sun.

Mr. Denning says (*Monthly Notices*, vol. 47, p. 39): "Meteors and meteoric radiants display by far the greatest profusion between July and December, and the densest region of radiation lies between 1° and 60° of R.A. This is, indeed, the most active part of the heavens, even as late as November, when it is some 110° distant from the apex of the Earth's way."

The positions of the 918 radiants given in Denning's catalogue (*Monthly Notices*, vol. 50), show about two-thirds grouped in the hemisphere from which the Sun is moving. It must be borne in mind, however, that these observations were chiefly made in the second half of the year.

A diagram at the end of M. Kleiber's treatise on meteor orbits, purporting to give corrected positions for these radiants, shows a more remarkable grouping of meteors behind the Sun's path.

Table VI. shows the apparent positions of the 918 radiants from Denning's catalogue.

Table VII. reproduces M. Kleiber's diagram (see also pp. 258 and 261 of his treatise).

I venture to submit—

1. That the explanation hitherto adopted of the semi-annual variation of meteors is inadequate.
2. That the variation is connected with and mainly due to the cosmical motion of the solar system.
3. That it renders highly probable the cosmical origin and motion of meteors.

1894 *June.*

Motion of Fireballs and Shooting Stars relatively to the Earth.

By W. F. Denning.

That there is a marked distinction in the general direction of motion of fireballs and ordinary shooting stars is a fact which has often impressed itself upon me during the progress of observation. I refer to the frequent tendency of fireballs to indicate radiants which are quite unknown and placed in regions of the sky singularly free from normal showers of shooting stars. In determining the real paths of fireballs from duplicate observations the same feature has been prominently suggested, and has led me incidentally to remark upon it on several occasions. The comparison of a large number of published results with particular regard to the positions of the radiants also bears out this conclusion in a manner not to be mistaken. There is no doubt that the majority

of fireballs move slowly, and that they are travelling in the same direction as the Earth (*i.e.* in direct orbits), for their points of radiation, instead of clustering in the eastern sky, similarly to those of the larger proportion of shooting stars, are placed in the western half of the firmament. Were the orbital distribution of fireballs a promiscuous and perfectly equable one, we should clearly expect that a far greater number of these bodies would meet the Earth than overtake it; but the reverse appears to be the rule from observation, wherefore it becomes obvious that their direction is of a special character.

Whenever an observer is watching for meteors and a large fireball suddenly bursts into view, the great probability is that it will not diverge from a well-defined star shower of the period, but from a westerly radiant which has, perhaps, never been recognised before, and which may only give this single indication of its activity. In proof of the fact alluded to, we have only to recall the paths of many of the finest meteors of recent years. For instance, the brilliant fireball that appeared in the evening twilight of April 22 last was directed from the region of *Perseus* in the north-western sky; the large detonating fireball of January 25 last had a radiant in *Cepheus* in the N.N.W.; the great meteor of 1893 October 1 emanated from near ζ *Draconis* in the N.W.; and many other examples might be readily quoted. In the latter case, though the fireball denoted a radiant in an unusual place, it nevertheless corresponded with the focus of an October meteor shower observed at Bristol in the years 1877 and 1885.

The surprise which has occasionally been expressed at the singular positions of fireball radiants as compared with the known radiants of shooting stars was induced by the assumption that the two classes of objects were identical in their directions. They were certainly not understood to offer a wide distinction in the respect named. But apparently this will have to be admitted, for it is obvious that the radiants of the larger and smaller forms of meteors are not fairly comparable, inasmuch as their distribution is of a special and dissimilar nature. Considering them separately, the radiant centres are in no way curious; indeed, the circumstance of a fireball leisurely streaming across the sky from a westerly direction may be regarded as quite a normal event, though decidedly unusual in the case of an ordinary shooting star.

I recently consulted a large number of fireball observations and radiant-positions * as given in the reports of the Luminous Meteor Committee of the British Association and in various scientific journals, and found that a considerable majority of the descriptions referred to fireballs, which must have overtaken the Earth in her orbit. I omitted the Perseid meteors altogether, as they form a very rich shower, and provide so many brilliant

* Many of these were carefully determined by Professor A. S. Herschel, who also, as secretary of the Meteor Committee, collected and recorded a vast number of useful observations both of fireballs and ordinary shooting stars.

members that their inclusion would have materially and unfairly affected the general result of the inquiry. But the examination was not a thorough one, nor can very exact results be obtained from the data preserved, since in some cases the paths observed have not been recorded with that degree of fidelity and completeness necessary to disclose the precise radiants.

The figures derived from a comparison of 321 of the best observed and largest fireballs which have appeared during the past thirty years are as under :

Large Fireballs.

		Percentage.
Number which met the Earth	131	40·8
Number which overtook the Earth ...	190	59·2

A striking excess is here shown in favour of those travelling in the same direction as the Earth, the numbers being in the proportion of nearly 3 to 2. With regard to shooting stars of the 1st magnitude, the values appear to be essentially different, for I examined a similar number taken at random from trustworthy catalogues, with the following result :

First Magnitude Shooting Stars.

		Percentage.
Number which met the Earth	207	64·5
Number which overtook the Earth ...	114	35·5

In this case there is a large excess on the side of those which met the Earth, as we should naturally expect from theoretical considerations. The difference in the percentages for fireballs and shooting stars is very significant, and apparently demonstrates that, while many of the former travel in direct orbits, the bulk of shooting stars emanate from the eastern region of the firmament, and with the characteristic swiftness of those pursuing retrograde paths.

The perfectly even distribution of meteoric orbits would suggest that a large proportion of meteors generally must fall from radiants in the forward or apex half, while but a relatively small number must diverge from points in the other, or anti-apex, half of the sphere, the calculated proportionate numbers given by Professor Alex. S. Herschel being 85 to 15. Comparing this with the results obtained from large fireballs and 1st magnitude shooting stars, we have the following values :

	Fireballs.	1st mag. Shooting Stars.	Computed No. on even distribution.
Radiants in apex half	40·8	64·5	85
Radiants in anti-apex half ...	59·2	35·5	15

There appear to be four times as many fireballs overtake the Earth as might be expected were their orbits equably arranged, and

without any particular regard to direction of motion. The proportion of fireballs of westerly extraction is so large that the law it suggests must hold good after every circumstance which may have unduly favoured its inception has been allowed for. The 1st magnitude shooting stars exhibit directions more consistent with theory, though the number overtaking the Earth seems to be more than double as many as would be supposed. It is probable, however, that the smaller shooting stars of 4th and 5th magnitudes would still more nearly correspond with the numbers computed on the assumption of a uniform arrangement of parabolic meteor streams. But it must be confessed that evidence is not wanting to show that even the latter are more often dispersed from southerly and westerly directions than would have been thought likely.

Many of the slow-moving and brilliant fireballs alluded to, apart from being distinctly unconformable with the radiants of ordinary meteors, appear to be solitary ; but whether this proceeds from the tenuity of their associated streams or from absolute isolation has yet to be ascertained from more extensive observation. I have occasionally made particular efforts to discover whether they were simply fine members of well-defined streams, the radiants of which might be detected by attentive watching. In a few instances this proved to be correct, but in many others not the slightest evidence could be gleaned of any accompanying showers. In each of the latter cases, therefore, the object may either have been single or connected with a meteor group nearly exhausted by the waste of its material during many past ages. Possibly there are groups of large meteors circulating in space without the attendance of the small fragments such as mainly compose our ordinary meteoric displays. It would seem from a comparison of the radiants of doubly observed fireballs that the same position will sometimes offer many repetitions, though the epoch is not always sufficiently near to favour the idea of absolute identity. Thus some splendid fireballs have been projected from the region north of *α Scorpii*, in the summer months, with radiants as follow, as deduced by Professor G. von Niessl, of Brünn :

	α	δ
	°	°
1883 June 3	250	−20
1883 June 3	248	−20
1878 June 7	249	−21
1873 June 17	249	−20
1879 July 13	246	−19

Several other large meteors have been directed from the same point in the succeeding months of August and September. There is also a display of similar character having its centre 5° S. of *θ Geminorum*, which is probably quite unconnected with the

Geminids of December 9–12. I have recorded the following meteors from it:

Date.	Hour.	Mag.	Path. From.	Path. To.	Length.	Notes.
	h m		° °	° °	°	
1880 Jan. 2	9 8	> 4	32 + 60	353 + 56	20	slow, bright train.
1877 Jan. 4	8 51	> ♀	134 + 45	169 + 44	25	slow, 2½ sec.
1886 Jan. 4	11 14	♀	164 + 58	215 + 52	29	slow 3 maxima.
1892 Jan. 11	8 5	♀	21 + 60	318 + 34	48	slow, 7 sec.

The radiant is at 97° + 29°, and a shower of small meteors apparently precedes it; for in 1886 December 20–29 I determined a radiant at 98° + 31° from eleven very slow-moving meteors. (No. 805 in my Catalogue of Radiants, *Monthly Notices*, May 1890, p. 465.)

In the case of radiants which appear to retain similar astronomical positions for several months, it will be found that the finest meteors come from them when they are opposite to the Sun's place, or even westward of that position. Thus there are Taurids in August, September, and October, but the Taurid fireballs come in November. There is a numerous display of meteors from near *α Arietis* during the months of July, August, and September, but it is not until October that it yields really brilliant fireballs. In *Cygnus* there is active radiation from near *κ* in the spring months, but it develops the finest meteors in August, and they are contemporary with the great Perseid display. It is so with a shower in Gemini at 120° + 29°, visible in the autumnal months, which seems to preserve its fireballs for display in April; and with a November–December radiant at 145° + 7° (near *o Leonis*), which supplies its most brilliant members in February and March. In considering these facts, the question arises whether the great difference in velocity has any influence on the brightness of the meteors meeting and those overtaking the Earth. The former are very quickly vaporised and destroyed, and perhaps before the brilliant effects of which they might otherwise be capable are developed. In the case of the slower meteors, the more gradual combustion may possibly be favourable to a more conspicuous aspect. As opposed to this suggestion, however, we must remember that very swift meteors like the Perseids and Leonids sometimes furnish magnificent fireballs, and from this we have to conclude that differences in the velocity of meteors can hardly be supposed to regulate their comparative brightness.

The proportionate numbers of meteor streams meeting and overtaking the Earth are no doubt in some degree affected by the time of night when observations are chiefly made. In the evening the half-sphere including the Earth's anti-apex is spread over most of the firmament, and may be expected to yield a majority of meteors overtaking the Earth. In the morning hours, and especially just before daylight, the half-sphere including the

Earth's apex is predominant, and will certainly supply an abundance of swift meteors meeting the Earth. The fact, therefore, that many of the largest fireballs are observed in the evening hours, when people are often out-of-doors, must certainly influence the numbers in some measure, as the fireballs appearing in the morning hours very frequently escape record, whereas evening fireballs are always seen. I believe, however, that though the circumstances are highly favourable to the detection of such fireballs as appear early in the night, there is undoubtedly a marked preponderance of these bodies then as compared with similar apparitions in the morning hours. If the prevailing conditions could all be smoothed, and perfectly fair averages were obtainable for comparison, there is every indication that the peculiarity here pointed out between the directions of fireballs and shooting stars would be conclusively upheld. The relative proportions given from my partial examination into the subject would no doubt be disturbed, but not so essentially as to controvert the singular fact they appear to affirm so distinctly.

A more complete and searching investigation than I have been enabled to make of the directions of the large fireballs recorded in scientific journals and proceedings of learned societies might readily be undertaken with a view to determine this question with greater certainty, but it would involve considerable labour. The object to be attained would, however, more than compensate for this. I would suggest that in the event of such a discussion being pursued the smaller bolides equal to ♃ and ♀ be excluded, and that only those described as brighter than ♀ be admitted. This would narrow down the work to reasonable limits, and properly confine it to the class of really brilliant fireballs. Meteors of special periodical showers like the Perseids, Leonids, and Andromedes should be rigorously excluded. If such an inquiry could be greatly extended so as to deal also with the smaller bodies it might be instructive to divide meteoric apparitions into four classes, and derive comparative results from each of them.

1. Fireballs of the most brilliant kind.
2. Bolides as bright as *Jupiter* or *Venus*.*
3. Meteors equal to 1st magnitude stars.
4. Shooting stars of the 4th and 5th magnitudes.

The differences found in the general directions of these several classes would, I believe, exhibit a well-marked gradation passing from the direct motion and slow speed of large fireballs to the rapid flights and retrograde orbits of the smallest visible shooting stars.

* Since this was written I have compared a large number of the radiant-positions of the small bolides estimated equal to *Jupiter* or *Venus*, and find that the percentages of their relative directions come nearly intermediate between the figures derived from large fireballs and 1st magnitude shooting stars.

Professor H. A. Newton, in discussing the "Relation of the Orbits of Meteorites to the Earth's Orbit," found that, from 116 observed meteoritic falls, 109 of them must have been following the Earth, while only seven met it. In further summing up his deductions he says that "nearly all the stones in the solar system are moving in direct orbits, very few in parabolic orbits, unless we can assume that stones moving in retrograde orbits for some reason—as, for example, their great relative velocity—may not have been able to pass through the air and to reach the ground in a solid form." He also concludes that the "larger meteorites are allied much more closely with the group of comets of short period than with the comets whose orbits are nearly parabolic" (*American Journal of Science*, 1888 July). This appears to be in agreement with the general directions of ordinary fireballs, which are somewhat rarely heard to detonate, and more rarely still seen to precipitate stones to the ground. But the silent fireballs may not be essentially different either in origin or character from the aerolites which have actually fallen. The observed varieties of appearance may have been introduced by differences in distance, in size, velocity, and condition as affecting their capacity to withstand disruption and dissipation from the heat generated by their violent impact with our atmosphere. Marked differences have been noticed in the composition of meteorites, as everyone knows, and these have led to their classification as Aerolites, Siderites, and Siderolites; but there is also a remarkable diversity in the character of certain terrestrial stones. The opinion has thus been gaining ground in late years that we may take the whole of meteoric objects as displaying a community of origin, the apparent departures from uniformity being due to the vicissitudes these bodies have to encounter in planetary space, to the variable conditions under which they individually become visible, and to the destructive reception they instantly meet with on rushing into the air.

Bristol:
1894 *June* 6.

The Discovery of Comets. By W. F. Denning.

Observers before devoting themselves to any particular line of work naturally consider the prospects offered and the amount of labour likely to be expended in ensuring reasonable success. Comet-seeking is generally regarded with dubious feelings, for though the observer may be attracted by the chance of effecting a discovery, he nevertheless hesitates before entering upon a research essentially requiring patience and perseverance in an

extreme degree. The tedious * work of sweeping the sky must be carried on with habit and system for a comparatively long period, though possibly no result whatever may accrue. Moreover, a difficulty which offers a serious impediment to observation has to be encountered in the vast numbers of nebulæ crowding the firmament. These objects are the bane of the comet-seeker, for the necessity of identifying many of them occupies considerable time; and occasionally they become a source of error, for scores of instances might be quoted where nebulæ have been mistaken for comets and actually announced as such.

The idea has sometimes occurred to me that it would be very interesting to learn from habitual and successful observers in this field what is the average number of hours expended in the discovery of a comet. I do not remember to have seen any such information, though it would undoubtedly be valuable as a guide. It is questionable whether the chief living comet-finders, such as Winnecke, Coggia, Borrelly, Swift, Barnard, and Brooks, have ever recorded the data necessary to afford instruction on the point referred to, but if they have preserved any material of the kind it is to be hoped it will be published. My own work in this department at Bristol has not been sufficiently extensive to furnish a trustworthy deduction, but it may be mentioned that five new comets † have been discovered as the outcome of 596 hours of sweeping. This is equivalent to one comet for every 119 hours of work. To put the matter another way: if an observer (under conditions precisely similar to my own) seeks for comets during two hours on each of sixty fine and moonless nights, he may expect to find one. If the search is prolonged each night for four hours, then the number of nights required for a discovery would be thirty, and so on. It should be stated that my figures are based on observations conducted with a 10-inch reflector, having comet eyepieces with powers of 32, 40, and 60, and fields of 72′, 65′, and 55′. I have generally used the power of 40, field 65′.

The average above stated would certainly not apply to everyone, for much depends upon the skill of the observer, upon the quality of the instrument used, and upon the place of observation. Different individuals would yield averages according to their capacity and to the circumstances under which they carried on the pursuit.‡ In a finer climate than that of England a man

* The work is, however, very rarely regarded as tedious by anyone prompted by genuine love for the subject. At times, it is true, in very cold weather, or when the observer's health is indifferent, an effort is required to continue it.

† One of these comets was discovered at the Lick Observatory on the evening preceding its detection at Bristol, but as my discovery was a perfectly independent one, I have thought it fair to include it in the total.

‡ Mr. W. R. Brooks once mentioned to me the case of an amateur who had sought in vain for comets during twenty years! On the other hand, a man may achieve a notable discovery by pure accident, like Mr. Holmes, of London, who, on 1892 November 6, having turned his telescope towards the great nebula in *Andromeda*, saw instead a bright naked-eye comet in the field!

would have an advantage; but I cannot help thinking that the skies of this country are often unduly maligned, and that there are abundant opportunities for all kinds of astronomical observation, if they are fully utilised whenever offered.

A very important factor remains to be mentioned as regards cometary discoveries and the success attained by one individual. This must largely depend upon the number of other observers in competition with him. It is obvious that if a single observer has the field practically to himself he will pick up many more comets than one who, working at another period, has to share these discoveries with perhaps half-a-dozen able men, at least as diligent and as successful as himself. This question as to the average number of hours involved in finding a new comet is evidently affected by so many considerations that it cannot be precisely ascertained, for the results in different cases must exhibit large discordances. Were several observers of lengthy experience to furnish details bearing on the point it might, however, be possible to deduce a good general average.

In concluding, I may allude to a class of phenomena often seen, though unsought for, by the comet-hunter. These are the telescopic meteors which nearly every night intrude themselves upon his attention. I have kept a record of the number seen during most of the time spent here in looking for comets, and the aggregate is 416 meteors in 466 hours of observation. Like the larger meteors visible to the unaided eye, they are more frequent in the summer and autumn than in winter and spring, for, dividing the year into two periods, the relative numbers come out as follows:

	Hours of Observation.	Meteors seen in Telescope.	Rate per Hour.
January to June	193½	135	0·70
July to December	272½	281	1·03

I have previously taken occasion to mention some peculiarities exhibited by these objects. Their short paths, general slowness of movement, and diminutive size induce the belief that they are situated at considerable distances beyond the average heights of ordinary shooting stars and fireballs.

Bristol:
1894 *May* 22.

Comet Gale (*b* 1894). By H. C. Russell, B.A., F.R.S.

The discovery of this comet was announced on April 4. On the 5th and other following days we obtained satisfactory observations of position, which are given below. The star camera has also been applied to the investigation of the comet's form, and has brought to light some remarkable changes. On April 5, with one hour's exposure, the comet is shown with well-marked central condensation, and a diameter of coma of 3′ and a very faint tail showing double; that is, as if two faint rays extended from the comet about 10′. From the 5th to the 23rd, bad weather and moonlight stopped the photographs; on the 23rd the photograph shows a very similar tail, with two rays, forming its bounding lines, extended for 20′, coma 6′ in diameter. On the 24th clouds limited the exposure to 55^m; central condensation decided, diameter of coma $7\frac{1}{2}'$, and well-marked long narrow tail 2′ across, more like Winnecke's comet 1868 than anything else I have seen. This long narrow tail was easily seen with the large equatorial, and traced 2°. In the photograph it extends to the edge of the plate $1\frac{1}{4}°$. Upon careful examination it appeared that at $\frac{3}{4}°$ from the comet the tail forked, but this feature is so faint that I cannot be sure of it.

On the 25th passing clouds and some haze interfered, but an exposure of $1^h\ 44^m$ was obtained, showing the coma 9′ in diameter, and a tail exactly similar to that on the 23rd, only much better defined and longer, extending $\frac{3}{4}°$, and the two bars evidently the bounding lines of the tail, much of which is very faint, and only visible with a suitable light. With the equatorial the tail was exceedingly faint, and only visible for 7^m or 8^m, although the comet was very distinct and the central condensation very marked, and apparently elongated in R.A. On the 26th we had another night of passing clouds, but a clear exposure of $1^h\ 16^m$ was obtained; the diameter of coma is 10′, the tail is neither single nor double, but is broad, diffused, and fan-shaped. With the equatorial no tail could be seen. On the 27th we had a fine clear night, and exposed the plate for three hours.* The coma in this photograph is 25′ in diameter, and the tail is again single, almost an exact counterpart of what it was on the 24th, except that it is slightly wider (3′); it extends to the edge of the plate $1\frac{1}{4}°$. With the equatorial it was easily seen and traced 2°, and was noted to be very similar to what it was on the 24th.

On the 28th it was cloudy, and on the 29th it was partially fine again, and an exposure of two hours was obtained between

* Mr. Russell sent with the paper silver prints of the photographs taken on April 25 and 27, which are in the library of the Society.

passing clouds, in this the coma is 15′ in diameter, and there is no defined tail, only a very faint and diffused something, visible with specially arranged illumination. With the equatorial nothing could be seen of it. The weather has been bad, and I should not have published these results, obtained under difficulty, but that I am quite convinced of the change from a wide or apparently double tail to a narrow one, as seen on the 24th and 27th, and the reverse on the 29th. The photographs seem to prove this beyond doubt, for on the 24th we have an exposure of 55^m, showing a decided long narrow tail and coma $7\frac{1}{2}'$ in diameter; while on the 25th, with an exposure of $1^h\,44^m$, showing the coma 9′ in diameter, or much larger than it was shown by the photograph of the 24th; and yet the tail is distinctly double and unlike what it was on the 24th, and this result is confirmed by independent observations with the equatorial. The repetition of the long narrow tail on the 27th, both photographically and visually, is also beyond doubt; and the photograph of the 30th, with coma 15′ in diameter, shows a much more effective exposure than that of the 24th, with coma only half that diameter; yet the narrow defined tail is missing both in telescope and photograph.

Observations of Comet Gale made with the 11½-inch Refractor of Sydney Observatory.

1894.	Syd. M. T.	Δ R.A.	Δ N.P.D.	Cp.	App. R.A.	Log p. Δ	App. N.P.D.	Log p. Δ	Red. ad l. app.	*	Observer.
	h m s	m s	′ ″		h m s		° ′ ″		s ″		
Apr. 5	7 59 17	− 2 15·31	−6 11·8	9	2 42 22·44	9·938	145 36 22·7	0·488	−1·00 +1·7	1	R. P. Sellors.
5	8 42 39	− 4 11·16	+1 57·8	8	2 42 34·62	9·926	145 36 17·8	0·624	−0·99 +1·8	2	„
5	8 56 6	− 5 34·96	+5 36·2	4	2 42 37·99	9·919	145 36 17·9	0·658	−1·00 +1·8	3	„
12	8 15 0	+ 4 47·20	+5 49·1	5	3 36 41·84	9·929	144 46 26·5	0·455	−1·06 +1·8	4	H. C. Russell.
12	8 49 1	− 4 38·23	−2 49·1	5	3 36 55·63	9·924	144 46 4·5	0·572	−1·06 +2·2	5	R. P. Sellors.
12	9 27 48	− 4 39·62	+9 1·5	4	3 37 11·04	9·907	144 45 33·4	0·673	−1·05 +2·3	6	„
16	9 11 8	−12 36·20	−1 9·8	2	4 19 48·30	9·906	142 54 42·2	0·570	−1·01 +3·8	7	„
17	7 36 27	− 3 59·70	−2 50·3	7	4 31 8·06	9·881	142 13 6·5	0·074	−1·00 +3·7	8	„
20	7 57 15	+ 4 35·92	−7 30·4	5	5 11 0·82	9·847	138 59 19·1	0·121	−0·87 +4·6	9	„
23	8 36 9	+ 4 31·66	+6 54·1	6	5 54 47·44	9·809	133 41 40·0	0·292	−0·65 +6·0	10	„
23	9 8 59	+ 0 29·90	+1 49·4	6	5 55 7·86	9·824	133 38 37·3	0·425	−0·63 +6·2	11	„
24	8 0 47	− 4 6·74	−3 21·8	7	6 9 18·36	9·754	131 26 20·6	0·101	−0·52 +6·8	12	„
25	7 55 17	+ 1 50·60	−2 38·8	6	6 24 8·11	9·718	128 49 55·1	0·098	−0·45 +6·8	13	„
26	7 57 51	+ 2 13·73	−8 38·7	5	6 38 57 68	9·690	125 53 36·2	0·159	−0·33 +6·9	14	„
27	7 37 40	+ 2 35·00	+2 25·5	10	6 53 20·30	9·626	122 41 55·4	0·142	−0·23 +6·9	15	„
27	8 12 35	− 1 21·26	+2 6·3	10	6 53 41·29	9·679	122 36 50·6	0·270	−0·20 +7·1	16	„

Mean Places of Comparison Stars, 1894·0.

*	R.A. 1894·0.	N.P.D. 1894·0.	Authority.
	h m s	° ′ ″	
1	2 44 38·75	145 42 32·8	Cord. Z. C. 1209.
2	2 46 46·77	145 34 18·2	St. 1169, Cord. G. C. 3051.
3	2 48 13·95	145 30 39·9	St. 1177, Cord. G. C. 3081.
4	3 31 55·70	144 40 35·6	St. 1494, Cord. G. C. 3970.
5	3 41 34·92	144 48 51·4	St. 1583, Cord. G. C. 4176.
6	3 41 51·71	144 36 29·6	St. 1586, Cord. G. C. 4185.
7	4 32 25·51	142 55 48·2	Cord. G. C. 5213.
8	4 35 8·76	142 15 53·1	Cord. G. C. 5267.
9	5 6 25·77	139 6 44·9	St. 2266, Cord. G. C. 5954.
10	5 50 16·43	133 34 39·9	St. 2684, Cord. G. C. 6965.
11	5 54 38·59	133 36 41·7	Cord. G. C. 7092.
12	6 13 25·62	131 29 35·6	Cord. G. C. 7607.
13	6 22 17·96	128 52 27·1	Cord. G. C. 7851.
14	6 36 44·28	126 2 8·0	Cord. G. C. 8255.
15	6 50 45·53	122 39 23·0	Cord. G. C. 8654.
16	6 55 2·75	122 34 37·2	St. 3338, Cord. G. C. 8769.

Observatory, Sydney:
1894 *April* 30.

Observations of Gale's Comet (b 1894) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

Greenwich Mean Solar Time.					Observer.	☄−✱R.A.	Corr. for Refraction.	Log factor of Parallax.	☄−✱N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1894.	d	h	m	s		m s	s		′ ″	″			h m s	° ′ ″	
May	12	9	48	26	C.D.	−0 39·40	0·00	9·4993	+ 0 33·2	0·0	0·7261	5	...	...	*a*
	12	11	57	7	„	+0 47·99	0·00	9·5933	− 3 46·2	−0·3	0·8001	2	9 37 27·97	69 29 9·8	*b*
	17	9	21	20	„	+0 36·92	0·00	9·4657	+ 2 27·1	0·0	0·6225	7	10 6 12·35	61 40 23·8	*c*
	17	9	22	32	B.	+0 36·51	0·00	9·4684	+ 2 24·1	0·0	0·6234	3	10 6 11·94	61 40 20·8	*c*
	18	10	3	26	A.C.	−3 18·47	0·00	9·5378	− 4 52·7	0·0	0·6452	2	10 11 22·06	60 26 31·7	*d*
	18	10	14	46	D.	−3 16·95	0·00	9·5519	− 5 10·4	0·0	0·6558	3	10 11 23·58	60 26 14·0	*d*
	18	10	51	51	J.	−3 11·51	0·00	9·5899	− 7 5·8	−0·1	0·6916	3	10 11 29·02	60 24 18·5	*d*
	21	9	24	33	H.	−0 52·49	0·00	9·4852	+22 38·9	+0·1	0·5666	3	10 24 59·34	57 27 9·2	*e*
	21	9	56	31	„	+1 42·81	0·00	9·5383	− 0 56·6	0·0	0·6016	6	10 25 6·26	57 26 3·5	*f*
	21	9	56	31	„	−1 25·00	0·00	9·5383	− 3 42·4	0·0	0·6016	6	10 25 5·81	57 26 4·4	*g*
	23	9	30	42	A.C.	−0 7·83	0·00	9·5040	+14 28·4	0·0	0·5491	3	...	...	*h*
	23	9	38	56	„	−1 40·12	0·00	9·5181	−14 30·9	0·0	0·5589	3	...	...	*i*

Greenwich Mean Solar Time.					Observer.	⊕ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	⊕ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1894.	d	h	m	s		m s	s		′ ″	″			h m s	° ′ ″	
May	24	9	22	39	B.	+1 1·61	0·00	9·4927	− 2 26·7	−0·1	0·5285	6	10 37 1·93	55 7 17·3	*j*
	24	9	27	25	„	−0 31·86	0·00	9·5025	+11 19·5	0·0	0·5346	2	10 37 2·53	55 7 16·4	*k*
	27	10	8	45	A.C.	−1 6·84	0·00	9·5794	− 0 4·2	0·0	0·5641	3	10 47 51·75	53 16 40·8	*l*
	29	13	27	51	B.	−1 27·91	+0·05	9·6467	−13 30·5	−0·8	0·8020	3	10 54 48·71	52 13 15·6	*m*
	30	10	32	31	A.C.	+3 52·12	0·00	9·6169	+ 3 7·8	0·0	0·5825	2	10 57 32·07	51 49 53·6	*n*
	30	10	39	9	„	+3 18·02	0·00	9·6233	− 4 27·2	0·0	0·5920	1	...	...	*o*
	31	9	41	25	B.	−2 4·95	0·00	9·5545	− 0 6·5	0·0	0·4991	3	11 0 27·07	51 26 4·3	*p*
	31	9	59	16	C.D.	−2 2·42	0·00	9·5811	− 0 16·6	0·0	0·5274	6	11 0 29·60	51 25 54·2	*p*
June	2	9	46	59	B.	+1 44·57	0·00	9·5708	− 3 51·7	0·0	0·4992	3	...	...	*q*
	2	9	55	46	„	−3 42·79	0·00	9·5834	+ 5 2·6	0·0	0·5133	3	11 6 15·12	50 41 41·7	*r*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires, and for the motion of the comet.

May 12.—Comet and stars faint, owing to milky sky.

May 21.—The three comparisons with star *e* are not considered good observations. Comet brilliant, approximately circular, elongated on the preceding side; nucleus.

The initials D., H., A.C., B., C.D., J., are those of Mr. Dyson, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Davidson, and Mr. Johns respectively.

Comparison Stars.

Star's Name.	R.A., 1894·0 h m s	N.P.D., 1894·0 ° ′ ″	Authority.
a. B.D. + 20°, 2367	9 37 29·	69 39·4	Bonn Observations, vol. iv.
b. B.D. + 20°, 2365	9 36 38·8	69 32 59·0	Bonn Observations, vol. vi.
c. W.B. (2) X., 47	10 5 34·04	61 38 1·1	Paris Catalogue, 1875.
d. W.B. (2) X., 246	10 14 39·07	60 31 28·7	Paris Catalogue, 1860 and 1875, and Cambridge Ast. Gesell. Zones.
e. 33 Leonis Minoris	10 25 50·28	57 4 35·3	Greenwich Catalogues, 1864, 1872, 1880, and Observations, 1893, 1894, Paris, 1875, Glasgow, 1890.
f. W.B. (2) X., 417, 418	10 23 21·92	57 27 5·2	Leiden Ast. Gesell. Zones, 287, 288.
g. W.B. (2) X., 480	10 26 29·26	57 29 51·7	Leiden Ast. Gesell. Zones, 169, 281.
h. B.D. + 34°, 2146	10 33 21·0	55 35·8	Bonn Observations, vol. iv.
i. B.D. + 34°, 2149	10 34 53·6	56 5·2	Bonn Observations, vol. iv.
j. W.B. (2) X., 682, 683	10 35 58·71	55 9 49·5	Leiden Zones, 170, 284, and Lund Zones, 188, 192.
k. W.B. (2) X., 719	10 37 32·77	54 56 2·3	Lund Ast. Gesell. Zones, 1, 163.
l. W.B. (2) X., 949	10 48 56·90	53 16 50·5	Lund Ast. Gesell. Zones, 188, 192, and Bonn Observations, vol. vi.
m. B.D. + 37°, 2146	10 56 14·84	52 26 52·4	Lund Ast. Gesell. Zones, 195, 198, and Bonn Observations, vol. vi.
n. B.D. + 38°, 2203	10 53 38·25	51 46 51·7	Lund Ast. Gesell. Zones, 174, 176.
o. B.D. + 38°, 2204	10 54 9·9	51 55·1	Bonn Observations, vol. iv.
p. W.B. (2) X., 1216, 1217	11 2 30·27	51 26 16·5	Lund Ast. Gesell. Zones, 174, 176.
q. B.D. + 39°, 2426	11 4 27·2	50 47·1	Bonn Observations, vol. iv.
r. B.D. + 39°, 2430	11 9 56·12	50 36 44·7	Lund Ast. Gesell. Zones, 168, 172.

Comparison star *d* was also used as a comparison star for Denning's Comet on March 31 last. It is a singular coincidence, and worthy of note, that the same star should be (quite accidentally) selected for two different comets at an interval of less than two months.

Royal Observatory, Greenwich:
1894 June 7.

Note on Comet Gale (*b* 1894). By Walter F. Gale.

The following elements have been computed by the Rev. Thomas Roseby, LL.D., of this city, from Mr. Tebbutt's observations of April 3, 6, and 12:

T	1894 April 13·757 G.M.T.	
π	170° 32′ 31″·6	Mean Equinox 1894·0.
Ω	206 14 23·8	
i	87 16 15·3	
log q	9·99349	

Motion direct.

The deduced middle place closely agrees with observation, the differences being

$$\begin{array}{cc} C-O & d\lambda \cos\beta - 0''\cdot88 \\ & d\beta \quad +7''\cdot3 \end{array}$$

The comet became visible to the naked eye on April 7, and on the 25th reached the 4th magnitude. At no time, however, was the tail exhibited to unassisted vision.

It may be worthy of record that on April 2 the tail was 1° long, very faint, and narrow. It increased in brightness until, on the 12th, it was approximately 2° long and 1′ wide, the diameter of the coma being 12′. On the 15th, when next observed, the tail had entirely disappeared—a change certainly not due to parallax. The comet remained a circular nebulosity, with considerable condensation, until the 20th, when a diffused extension was visible, which subsequently appeared as an ill-defined tail 40′ in length.

Paddington, Sydney, N.S.W.:
1894 *May* 1.

Observations of Gale's Comet, made at the Cambridge Observatory, with Northumberland Equatorial and Square Bar Micrometer.

(*Communicated by Sir R. S. Ball.*)

G.M.T. corrected for Aberrn. 1894.	Geoc. R.A.	Geoc. Decl.	Compared Stars. R.A. 1894·0.	Compared Stars. Decl. 1894·0	Authority.	No. of Comparisons.
	h m s	° ′ ″	h m s	° ′ ″		
May 4·39656	8 28 36·62	− 3 6 47·5	8 31 13·29	− 3 8 32·3	Lalande 16947	5
7·38336	8 57 48·70	+ 7 26 4·0	8 57 36·89	+ 7 13 59·5	Bessel 8h 1423	6
7·39526	8 57 55·22	7 27 49·5	8 57 36·89	7 13 59·5	„ „	6
7·45629	8 58 27·91	7 40 53·4	8 57 6·31	7 42 56·4	Bessel 8h 1414	5
10·39812	9 22 36·30	15 52 40·7	9 23 32·57	15 50 5·4	„ 9h 450	9
10·39812	9 22 36·84	15 52 40·3	9 24 46·51	15 43 36·2	„ 9h 472	
17·40137	10 6 17·19	28 20 50·8	10 5 34·02	28 21 56·0	Camb. Zones, 3 obs.	10
18·41513	10 11 23·63	29 33 42·4	10 14 39·06	29 28 30·9	„ „	10
21·42544	10 25 11·19	32 34 56·5	10 23 22·61	32 32 52·7	Bessel 10h 417, 418	10
21·42544	10 25 9·26	32 34 57·2	10 26 28·46	32 30 7·1	„ 10h 480	
23·43412	10 33 22·53	34 12 15·4	10 40 52·20	34 7 1·7	„ 10h 789	5
23·43412	10 33 22·67	34 12 15·8	10 41 47·46	34 8 56·7	„ 10h 805	
24·43281	10 37 13·74	34 54 41·6	10 35 58·84	34 50 10·7	„ 10h 682, 683	10
31·43935	11 0 34·68	38 35 0·5	11 2 29·81	38 33 48·4	„ 10h 1216, 1217	10
31·43935	11 0 34·90	38 34 57·8	11 4 55·03	38 30 25·6	„ 11h 26	

Notes.

May 7.—The comparisons with Bessel 8h 1423 were unsatisfactory. The comet crossed too low in the field when the star was suitably placed.

May 21.—The results seem to indicate proper motion in one of the compared stars, or an error in Bessel's Catalogue of 2s Right Ascension.

Orbit-Elements of Comet Gale (*b* 1894). By John Tebbutt.

This comet was discovered by Mr. Walter F. Gale, of Paddington, near Sydney, on April 1, and the discovery was communicated to me by him on the 3rd. I was successful in obtaining a set of comparisons on the 3rd, and on the following day I telegraphed the resulting position with the name of the discoverer to the Melbourne Observatory. The first approximate elements are by Mr. R. T. A. Innes, of Sydney, from my observations of the 4th, 8th, and 12th. Another set was derived by Mr. Baracchi, of the Melbourne Observatory, from the Windsor observation of the 3rd, and Melbourne positions for the 7th and 11th; and, lastly, another set was obtained by the Rev. Dr. Roseby, of Marrickville, near Sydney, from the Windsor positions for the 3rd, 6th, and 12th. These three independent results agree remarkably well. I have now much pleasure in sending to you my own determination from the Windsor positions for the 3rd, 12th, and 21st, but they are as yet uncorrected for aberration or parallax. They are as follows:

$T = 1894$ April $13^d{\cdot}53267$. G.M.T.

$\omega = 324^\circ\ 16'\ 19''$

$\Omega = 206\ 19\ 24$ from M. Equinox 1894·0

$i = 87\ 6\ 36$

$\log q = 9{\cdot}992829$

$q = 0{\cdot}98362$

These elements do not differ from those obtained by the three computers already named more than might be expected from the longer arc embraced between the extreme observations. The most interesting feature of the orbit is perhaps its near approach to the Earth's orbit at the ascending node. The passage of the ascending node will occur on May $10^d{\cdot}28$, G.M.T., the difference between the *radii vectores* of the Earth and comet at that point being only 0·0817 of the Sun's mean distance from the Earth. This corresponds to a distance of 7,500,000 miles. The Earth, however, passed the point of near approach a little before Greenwich noon on April 16. I trust to be able to complete a fine series of observations of this comet.

Private Observatory, Windsor, N.S.W.
1894 *April* 29.

Ephemeris of the Satellites of Mars, 1894. By A. Marth.

Greenwich Noon. 1894.		*Phobos.*				*Deimos.*				
		P	a_1	b_1	u_1-U	a_2	b_2	u_2-U	U	B
		°	″	″	°	″	″	°	°	°
July	30	326·47	18·41	− 6·47	122·12	46·06	− 16·19	119·14	339·37	− 20·58
Aug.	1	326·20	18·70	6·50	218·86	46·78	16·26	328·47	340·38	20·35
	3	325·95	18·99	6·53	315·64	47·52	16·34	177·83	341·36	20·12
	5	325·72	19·29	6·56	52·44	48·27	16·42	27·22	342·32	19·89
	7	325·50	19·60	6·59	149·28	49·04	16·50	236·64	343·24	19·66
	9	325·30	19·91	− 6·62	246·15	49·83	− 16·58	86·09	344·13	− 19·44
	11	325·11	20·23	6·66	343·05	50·63	16·66	295·58	344·98	19·22
	13	324·93	20·56	6·69	79·98	51·35	16·75	145·10	345·80	19·00
	15	324·77	20·90	6·73	176·95	52·29	16·84	354·65	346·59	18·79
	17	324·62	21·24	6·77	273·96	53·15	16·94	204·24	347·34	18·59
	19	324·49	21·59	− 6·81	11·00	54·02	− 17·04	53·87	348·05	− 18·39
	21	324·37	21·95	6·85	108·08	54·91	17·15	263·54	348·72	18·20
	23	324·26	22·31	6·90	205·20	55·82	17·27	113·25	349·35	18·02
	25	324·17	22·68	6·95	302·36	56·75	17·40	323·01	349·94	17·85
	27	324·08	23·05	7·01	39·57	57·69	17·54	172·81	350·48	17·70
	29	324·00	23·43	− 7·07	136·82	58·65	− 17·69	22·65	350·97	− 17·56
	31	323·93	23·82	7·14	234·12	59·61	17·86	232·54	351·42	17·43
Sept.	2	323·87	24·21	7·21	331·47	60·59	18·04	82·48	351·82	17·32
	4	323·82	24·60	7·29	68·87	61·57	18·23	292·47	352·17	17·23
	6	323·78	24·99	7·37	166·31	62·55	18·45	142·51	352·46	17·15
	8	323·75	25·39	− 7·46	263·81	63·54	− 18·68	352·61	352·71	− 17·09
	10	323·72	25·78	7·56	1·36	64·52	18·92	202·76	352·90	17·06
	12	323·70	26·17	7·67	98·96	65·50	19·19	52·96	353·03	17·04
	14	323·69	26·56	7·79	196·62	66·46	19·48	263·21	353·11	17·04
	16	323·68	26·94	7·91	294·33	67·41	19·78	113·52	353·14	17·07
	18	323·68	27·31	− 8·04	32·09	68·34	− 20·11	323·89	353·10	− 17·11
	20	323·69	27·67	8·17	129·91	69·24	20·45	174·32	353·01	17·18
	22	323·70	28·01	8·32	227·79	70·11	20·82	24·80	352·86	17·27
	24	323·73	28·34	8·47	325·72	70·93	21·19	235·34	352·66	17·38
	26	323·76	28·65	8·63	63·70	71·70	21·59	85·93	352·40	17·52
	28	323·80	28·94	− 8·79	161·73	72·41	− 21·99	296·58	352·08	− 17·68
	30	323·85	29·19	8·95	259·82	73·05	22·40	147·28	351·71	17·85
Oct.	2	323·90	29·42	9·12	357·95	73·62	22·82	358·03	351·29	18·05
	4	323·96	29·61	9·28	96·12	74·11	23·23	208·83	350·82	18·27
	6	324·03	29·77	9·45	194·34	74·50	23·64	59·67	350·32	18·50
	8	324·11	29·89	− 9·61	292·59	74·79	− 24·04	270·54	349·77	− 18·75

		Phobos.			*Deimos.*				
Greenwich Noon. 1894.	P	a_1	b_1	u_1-U	a_2	b_2	u_2-U	U	B
	°	"	"	°	"	"	°	°	°
Oct. 10	324·20	29·96	9·76	30·86	74·98	24·42	121·44	349·19	19·01
12	324·30	30·00	9·90	129·16	75·07	24·78	332·37	348·59	19·28
14	324·41	29·99	10·04	227·47	75·04	25·11	183·32	347·96	19·55
16	324·53	29·93	10·16	325·79	74·90	25·41	34·29	347·32	19·83
18	324·65	29·83	−10·26	64·12	74·65	−25·68	245·26	346·67	−20·12
20	324·77	29·68	10·35	162·45	74·28	25·90	96·23	346·02	20·41
22	324·90	29·49	10·42	260·77	73·81	26·08	307·20	345·37	20·69
24	325·03	29·26	10·47	359·07	73·23	26·21	158·15	344·73	20·97
26	325·16	28·99	10·51	97·35	72·54	26·29	9·09	344·11	21·25
28	325·29	28·68	−10·52	195·60	71·76	−26·32	220·00	343·52	−21·52
30	325·42	28·33	10·51	293·82	70·90	26·30	70·88	342·95	21·78
Nov. 1	325·54	27·95	10·48	32·00	69·95	26·23	281·73	342·42	22·03
3	325·65	27·55	10·44	130·13	68·93	26·12	132·53	341·94	22·27
5	325·75	27·12	10·37	228·22	67·86	25·96	343·28	341·50	22·49
7	325·85	26·67	−10·29	326·25	66·73	−25·75	193·99	341·10	−22·70
9	325·93	26·20	10·19	64·22	65·56	25·51	44·64	340·76	22·90
11	326·00	25·72	10·08	162·14	64·36	25·23	255·24	340·47	23·08
13	326·05	25·23	9·96	260·00	63·13	24·92	105·78	340·24	23·25
15	326·09	24·73	9·82	357·79	61·89	24·58	316·26	340·06	23·40
Nov. 17	326·11	24·23	−9·67	95·53	60·64	−24·21	166·69	339·94	−23·53
19	326·12	23·73	9·52	193·21	59·38	23·82	17·06	339·88	23·65
21	326·12	23·22	9·36	290·83	58·12	23·41	227·37	339·87	23·76
23	326·10	22·72	9·19	28·39	56·87	22·99	77·63	339·92	23·85
25	326·06	22·23	9·02	125·90	55·63	22·56	287·83	340·02	23·93
27	326·01	21·74	−8·84	223·35	54·39	−22·12	137·98	340·18	−23·99
29	325·94	21·26	8·66	320·74	53·18	21·67	348·07	340·39	24·04
Dec. 1	325·86	20·78	8·47	58·07	51·99	21·21	198·11	340·65	24·07
3	325·77	20·31	8·29	155·35	50·82	20·74	48·10	340·96	24·09
5	325·67	19·85	8·10	252·59	49·68	20·28	258·04	341·32	24·09
7	325·55	19·41	−7·92	349·78	48·57	−19·82	107·93	341·72	−24·08
9	325·43	18·97	7·74	86·92	47·48	19·36	317·78	342·17	24·06
11	325·29	18·55	7·55	184·02	46·42	18·90	167·59	342·66	24·03
13	325·15	18·13	7·37	281·07	45·38	18·44	17·36	343·19	23·98
15	325·00	17·73	7·19	18·09	44·38	17·99	227·09	343·76	23·92
17	324·85	17·34	−7·01	115·07	43·40	−17·54	76·79	344·36	23·84

The differences of successive values of $u_1 - U$ vary between 2256°·74 and 2258°·33, and of $u_2 - U$ between 569°·33 and 570°·97. The values of P, a, b, $u - U$ being interpolated directly for the times for which the positions of the satellites are required, the position-angles p and apparent distances s of the satellites are found by means of the formulæ :

$$s \sin (p - P) = a \sin (u - U)$$
$$s \cos (p - P) = b \cos (u - U).$$

Approximate Greenwich times, at which the satellites will be at their greatest elongations (e in position P + 90°, and w in position P − 90°); the designation, in the case of *Phobos*, belonging to both given times, so that an elongation on the opposite side occurs at mid-time between them :

	Phobos.		*Deimos.*			*Phobos.*		*Deimos.*
1894.	h		h	h	1894.	h		h	h
July 30	14·6	*e*	22·3	12·7 *w*	Aug. 24	11·8	*e*	19·5	19·5 *w*
31	13·6	*e*	21·3	19·1 *w*	25	10 8	*e*	18·4	10·7 *e*
Aug. 1	12·6	*e*	20·2	10·2 *e*	26	13 6	*w*	21·2	17·0 *e*
2	11·5	*e*	19·2	16·6 *e*	27	12 6	*w*	20·2	23·3 *e*
3	14·3	*w*	22·0	22·9 *e*	28	11·5	*w*	19·2	14·5 *w*
4	13·3	*w*	21·0	14·1 *w*	29	14·3	*e*	22·0	20·8 *w*
5	12·3	*w*	19·9	20·5 *w*	30	13·3	*e*	20·9	12·0 *e*
6	11·2	*w*	18·9	11·6 *e*	31	12·2	*e*	19·9	18·3 *e*
7	14·0	*e*	21·7	18·0 *e*	Sept. 1	11·2	*e*	18·9	9·5 *w*
8	13·0	*e*	20·7	9·2 *w*	2	14·0	*w*	21·7	15·8 *w*
9	12·0	*e*	19·6	15·5 *w*	3	13·0	*w*	20·6	22·1 *w*
10	11·0	*e*	18·6	21·8 *w*	4	11·9	*w*	19·6	13·3 *e*
11	13·8	*w*	21·4	13·0 *e*	5	10·9	*w*	18·5	19·6 *e*
12	12·7	*w*	20·4	19·3 *e*	6	13·7	*e*	21·3	10·7 *w*
13	11·7	*w*	19·3	10·5 *w*	7	12·6	*e*	20·3	17·0 *w*
14	14·5	*e*	22·1	16·9 *w*	8	11·6	*e*	19·3	23·4 *w*
15	13·5	*e*	21·1	23·2 *w*	9	10·6	*e*	18·2	14·5 *e*
16	12·4	*e*	20·1	14·4 *e*	10	13·4	*w*	21·0	20·8 *e*
17	11·4	*e*	19·1	20·7 *e*	11	12·3	*w*	20·0	12·0 *w*
18	14·2	*w*	21·8	11·9 *w*	12	11·3	*w*	18·9	18·3 *w*
19	13·2	*w*	20·8	18·2 *w*	13	10·2	*w*	17·9	9·4 *e*
20	12·1	*w*	19·8	9·4 *e*	14	13·0	*e*	20·7	15·7 *e*
21	11·1	*w*	18·8	15·7 *e*	15	12·0	*e*	19·6	22·0 *e*
22	13·9	*e*	21·5	22·0 *e*	16	11·0	*e*	18·6	13·2 *w*
23	12·9	*e*	20·5	13·2 *w*	17	9·9	*e*	17·6	19·5 *w*

Ephemeris for Physical Observations

Greenwich Noon.	Position-angle of ♃'s Axis. P	L−O	Diff.	B	A−L	Apparent Diameter. Equat.	Phase.	Polar.
1894.	°	°		°	°	″	″	″
July 30	359·123	310·908	398	+2·422	− 7·520	33·50	0·14	31·35
Aug. 1	359·309	311·306	394	2·416	7·745	33·62	·15	31·46
3	359·493	311·700	389	2·409	7·965	33·74	·16	31·57
5	359·674	312·089	383	2·402	8·180	33·86	·17	31·69
7	359·853	312·472	377	2·395	8·390	33·99	·18	31·81
9	0·029	312·849	372	+2·388	− 8·594	34·13	0·19	31·94
11	0·203	313·221	367	2·381	8·793	34·27	·20	32·07
13	0·374	313·588	360	2·374	8·986	34·41	·21	32·20
15	0·542	313·948	354	2·367	9·173	34·56	·22	32·34
17	0·707	314·302	347	2·360	9·353	34·71	·23	32·48
19	0·869	314·649	340	+2·353	− 9·528	34·86	0·24	32·62
21	1·028	314·989	334	2·346	9·695	35·02	·25	32·77
23	1·184	315·323	327	2·340	9·856	35·19	·26	32·93
25	1·336	315·650	320	2·333	10·010	35·36	·27	33·09
27	1·485	315·970	312	2·327	10·157	35·53	·28	33·25
29	1·630	316·282	304	+2·320	−10·296	35·71	0·29	33·42
31	1·772	316·586	296	2·314	10·427	35·89	·30	33·59
Sept. 2	1·910	316·882	287	2·307	10·550	36·08	·30	33·76
4	2·044	317·169	279	2·301	10·665	36·27	·31	33·94
6	2·174	317·448	270	2·295	10·771	36·46	·32	34·12
8	2·300	317·718	261	+2·289	−10·869	36·66	0·33	34·31
10	2·421	317·979	252	2·283	10·957	36·87	·34	34·50
12	2·538	318·231	242	2·277	11·036	37·08	·34	34·69
14	2·651	318·473	233	2·271	11·106	37·29	·35	34·89
16	2·759	318·706	223	2·265	11·166	37·50	·35	35·09
18	2·862	318·929	212	+2·260	−11·217	37·72	0·36	35·30
20	2·961	319·141	202	2·255	11·257	37·94	·37	35·51
22	3·055	319·343	192	2·250	11·287	38·17	·37	35·72
24	3·144	319·535	181	2·245	11·306	38·40	·37	35·93
26	3·227	319·716	169	2·240	11·314	38·63	·38	36·15
28	3·305	319·885	157	+2·235	−11·311	38·87	0·38	36·37
30	3·378	320·042	146	2·230	11·297	39·11	·38	36·60
Oct. 2	3·446	320·188	135	2·226	11·271	39·35	·38	36·82
4	3·508	320·323	122	2·222	11·233	39·60	·38	37·05

of Jupiter, 1894-95. By A. Marth.

Greenwich Noon.	Brightness.	Longitude of 's Central Meridn. (877°·90) I.	(870° 27) II.	Corr. for Phase.	Light-time.	A−O	B
1894.	m	°	°	°	m	°	°
July 30	−1·57	228·63	238·28	+0·25	48·331	303·3910	+2·5612
Aug. 1	−1·58	184·13	178·52	·26	48·164	303·5645	2·5561
3	−1·59	139·64	118·77	·28	47·992	303·7379	2·5510
5	−1·59	95·16	59·03	·29	47·815	303·9113	2·5458
7	−1·60	50·69	359·30	·31	47·634	304·0847	2·5406
9	−1·61	6·23	299·58	+0·32	47·447	304·2580	+2·5354
11	−1·62	321·77	239·86	·34	47·256	304·4313	2·5302
13	−1·63	277·32	180·15	·35	47·060	304·6045	2·5249
15	−1·63	232·88	120·45	·37	46·860	304·7777	2·5196
17	−1·64	188·45	60·76	·38	46·655	304·9508	2·5143
19	−1·65	144·03	1·08	+0·40	46·447	305·1239	+2·5090
21	−1·66	99·62	301·41	·41	46·234	305·2969	2·5037
23	−1·67	55·22	241·75	·42	46·018	305·4699	2·4983
25	−1·68	10·83	182·09	·44	45·797	305·6428	2·4929
27	−1·69	326·45	122·45	·45	45·573	305·8157	2·4875
29	−1·70	282·07	62·82	+0·46	45·346	305·9885	+2·4821
31	−1·71	237·71	3·19	·47	45·115	306·1613	2·4766
Sept. 2	−1·72	193·36	303·57	·48	44·882	306·3340	2·4711
4	−1·73	149·01	243·97	·49	44·645	306·5067	2·4656
6	−1·75	104·68	184·38	·50	44·406	306·6794	2·4601
8	−1·76	60·36	124·79	+0·51	44·164	306·8520	+2·4546
10	−1·77	16·04	65·22	·52	43·921	307·0246	2·4490
12	−1·78	331·74	5·65	·53	43·675	307·1971	2·4434
14	−1·79	287·45	306·10	·54	43·427	307·3696	2·4378
16	−1·80	243·17	246·56	·54	43·177	307·5420	2·4322
18	−1·82	198·90	187·03	+0·55	42·926	307·7143	+2·4266
20	−1·83	154·64	127·51	·55	42·674	307·8866	2·4209
22	−1·84	110·39	68·00	·55	42·421	308·0589	2·4152
24	−1·85	66·16	8·50	·56	42·167	308·2311	2·4095
26	−1·87	21·93	309·01	·56	41·912	308·4033	2·4038
28	−1·88	337 72	249·54	+0·56	41·657	308·5754	+2·3981
30	−1·89	293·52	190·08	·55	41·402	308·7475	2·3923
Oct. 2	−1·91	249·33	130·62	·55	41·147	308·9195	2·3865
4	−1·92	205·15	71·18	·55	40·898	309·0914	2·3807

Ephemeris for Physical Observations

Greenwich Noon.	Position-angle of U's Axis. P	L−O	Diff.	B	A−L	Apparent Diameter. Equat.	Phase.	Polar.
1894.	°	°		°	°	″	″	″
July 30	359·123	310·908	398	+2·422	− 7·520	33·50	0·14	31·35
Aug. 1	359·309	311·306	394	2·416	7·745	33·62	·15	31·46
3	359·493	311·700	389	2·409	7·965	33·74	·16	31·57
5	359·674	312·089	383	2·402	8·180	33·86	·17	31·69
7	359·853	312·472	377	2·395	8·390	33·99	·18	31·81
9	0·029	312·849	372	+2·388	− 8·594	34·13	0·19	31·94
11	0·203	313·221	367	2·381	8·793	34·27	·20	32·07
13	0·374	313·588	360	2·374	8·986	34·41	·21	32·20
15	0·542	313·948	354	2·367	9·173	34·56	·22	32·34
17	0·707	314·302	347	2·360	9·353	34·71	·23	32·48
19	0·869	314·649	340	+2·353	− 9·528	34·86	0·24	32·62
21	1·028	314·989	334	2·346	9·695	35·02	·25	32·77
23	1·184	315·323	327	2·340	9·856	35·19	·26	32·93
25	1·336	315·650	320	2·333	10·010	35·36	·27	33·09
27	1·485	315·970	312	2·327	10·157	35·53	·28	33·25
29	1·630	316·282	304	+2·320	−10·296	35·71	0·29	33·42
31	1·772	316·586	296	2·314	10·427	35·89	·30	33·59
Sept. 2	1·910	316·882	287	2·307	10·550	36·08	·30	33·76
4	2·044	317·169	279	2·301	10·665	36·27	·31	33·94
6	2·174	317·448	270	2·295	10·771	36·46	·32	34·12
8	2·300	317·718	261	+2·289	−10·869	36·66	0·33	34·31
10	2·421	317·979	252	2·283	10·957	36·87	·34	34·50
12	2·538	318·231	242	2·277	11·036	37·08	·34	34·69
14	2·651	318·473	233	2·271	11·106	37·29	·35	34·89
16	2·759	318·706	223	2·265	11·166	37·50	·35	35·09
18	2·862	318·929	212	+2·260	−11·217	37·72	0·36	35·30
20	2·961	319·141	202	2·255	11·257	37·94	·37	35·51
22	3·055	319·343	192	2·250	11·287	38·17	·37	35·72
24	3·144	319·535	181	2·245	11·306	38·40	·37	35·93
26	3·227	319·716	169	2·240	11·314	38·63	·38	36·15
28	3·305	319·885	157	+2·235	−11·311	38·87	0·38	36·37
30	3·378	320·042	146	2·230	11·297	39·11	·38	36·60
Oct. 2	3·446	320·188	135	2·226	11·271	39·35	·38	36·82
4	3·508	320·323	122	2·222	11·233	39·60	·38	37·05

of Jupiter, 1894-95. By A. Marth.

Greenwich Noon.	Brightness.	Longitude of 's Central Meridn. (877°·90) I.	(870° ·27) II.	Corr. for Phase.	Light-time.	A−O	B
1894.	m	°	°	°	m	°	°
July 30	−1·57	228·63	238·28	+0·25	48·331	303·3910	+2·5612
Aug. 1	−1·58	184·13	178·52	·26	48·164	303·5645	2·5561
3	−1·59	139·64	118·77	·28	47·992	303·7379	2·5510
5	−1·59	95·16	59·03	·29	47·815	303·9113	2·5458
7	−1·60	50·69	359·30	·31	47·634	304·0847	2·5406
9	−1·61	6·23	299·58	+0·32	47·447	304·2580	+2·5354
11	−1·62	321·77	239·86	·34	47·256	304·4313	2·5302
13	−1·63	277·32	180·15	·35	47·060	304·6045	2·5249
15	−1·63	232·88	120·45	·37	46·860	304·7777	2·5196
17	−1·64	188·45	60·76	·38	46·655	304·9508	2·5143
19	−1·65	144·03	1·08	+0·40	46·447	305·1239	+2·5090
21	−1·66	99·62	301·41	·41	46·234	305·2969	2·5037
23	−1·67	55·22	241·75	·42	46·018	305·4699	2·4983
25	−1·68	10·83	182·09	·44	45·797	305·6428	2·4929
27	−1·69	326·45	122·45	·45	45·573	305·8157	2·4875
29	−1·70	282·07	62·82	+0·46	45·346	305·9885	+2·4821
31	−1·71	237·71	3·19	·47	45·115	306·1613	2·4766
Sept. 2	−1·72	193·36	303·57	·48	44·882	306·3340	2·4711
4	−1·73	149·01	243·97	·49	44·645	306·5067	2·4656
6	−1·75	104·68	184·38	·50	44·406	306·6794	2·4601
8	−1·76	60·36	124·79	+0·51	44·164	306·8520	+2·4546
10	−1·77	16·04	65·22	·52	43·921	307·0246	2·4490
12	−1·78	331·74	5·65	·53	43·675	307·1971	2·4434
14	−1·79	287·45	306·10	·54	43·427	307·3696	2·4378
16	−1·80	243·17	246·56	·54	43·177	307·5420	2·4322
18	−1·82	198·90	187·03	+0·55	42·926	307·7143	+2·4266
20	−1·83	154·64	127·51	·55	42·674	307·8866	2·4209
22	−1·84	110·39	68·00	·55	42·421	308·0589	2·4152
24	−1·85	66·16	8·50	·56	42·167	308·2311	2·4095
26	−1·87	21·93	309·01	·56	41·912	308·4033	2·4038
28	−1·88	337 72	249·54	+0·56	41·657	308·5754	+2·3981
30	−1·89	293·52	190·08	·55	41·402	308·7475	2·3923
Oct. 2	−1·91	249·33	130·62	·55	41·147	308·9195	2·3865
4	−1·92	205·15	71·18	·55	40·898	309·0914	2·3807

Greenwich Noon.		Position-angle of ♃'s Axis. P	L−O	Diff.	B	A−L	Apparent Diameter. Equat.	Phase.	Polar.
1894.		°	°			°	″	″	″
Oct.	6	3·565	320·445	110	2·218	11·184	39·84	·38	37·28
	8	3·616	320·555	97	+2·214	−11·122	40·09	0·38	37·52
	10	3·661	320·652	85	2·210	11·047	40·34	·37	37·75
	12	3·700	320·737	72	2·207	10·960	40·60	·37	37·99
	14	3·733	320·809	59	2·204	10·861	40·85	·37	38·22
	16	3·760	320·868	47	2·201	10·748	41·10	·36	38·46
	18	3·782	320·915	33	+2·198	−10·623	41·36	0·35	38·70
	20	3·798	320·948	20	2·195	10·485	41·62	·35	38·94
	22	3·807	320·968	6	2·193	10·333	41·87	·34	39·18
	24	3·810	320·974	7	2·190	10·168	42·12	·33	39·42
	26	3·807	320·967	20	2·188	9·990	42·37	·32	39·65
	28	3·798	220·947	34	+2·186	− 9·798	42·62	0·31	39·89
	30	3·782	320·913	47	2·185	9·593	42·87	·30	40·12
Nov.	1	3·760	320·866	61	2·183	9·374	43·12	·29	40·35
	3	3·732	320·805	74	2·182	9·142	43·36	·28	40·58
	5	3·698	320·731	87	2·181	8·897	43·60	·26	40·80
	7	3·658	320·644	100	+2·180	− 8·639	43·84	0·25	41·02
	9	3·612	320·544	113	2·179	8·368	44·07	·23	41·24
	11	3·560	320·431	125	2·178	8·084	44·29	·22	41·45
	13	3·502	320·306	138	2·178	7·788	44·51	·21	41·65
	15	3·439	320·168	150	2·177	7·479	44·73	·19	41·85
	17	3·370	320·018	161	+2·177	− 7·158	44·93	0·18	42·04
	19	3·295	319·857	172	2·177	6·826	45·13	·16	42·23
	21	3·215	319·685	184	2·177	6·483	45·32	·15	42·41
	23	3·130	319·501	194	2·176	6·129	45·51	·13	42·58
	25	3·040	319·307	204	2·176	5·764	45·68	·12	42·74
	27	2·946	319·103	213	+2·176	− 5·389	45·84	0·10	42·90
	29	2·847	318·890	223	2·176	5·005	45·99	·09	43·04
Dec.	1	2·744	318·667	230	2·176	4·612	46·13	·07	43·17
	3	2·637	318·437	238	2·177	4·211	46·26	·06	43·29
	5	2·526	318·199	245	2·177	3·803	46·38	·05	43·40
	7	2·412	317·954	251	+2·177	− 3·387	46·48	0·04	43·50
	9	2·296	317·703	256	2·177	2·966	46·58	·03	43·58
	11	2·177	317·447	261	2·177	2·540	46·65	·02	43·66
	13	2·056	317·186	265	2·177	2·109	46·72	·02	43·72
	15	1·933	316·921	267	2·177	1·674	46·77	·01	43·77
	17	1·808	316·654		+2·177	− 1·236	46·81	0·01	43·80

Greenwich Noon.	Brightness.	Longitude of ℳ's Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O	B
1894.	m	°	°	°	m	°	°
Oct. 6	−1·93	160·98	11·75	·54	40·640	309·2633	2·3749
8	−1·95	116·82	312·34	−0·54	40·388	309·4352	+2·3691
10	−1·96	72·68	252·93	·53	40·137	309·6070	2·3633
12	−1·97	28·55	193·54	·52	39·888	309·7788	2·3574
14	−1·99	344·42	134·15	·51	39·640	309·9505	2·3515
16	−2·00	300·31	74·78	·50	39·395	310·1222	2·3456
18	−2·01	256·22	15·42	+0·49	39·153	310·2938	+2·3397
20	−2·03	212·13	316·07	·48	38·913	310·4654	2·3337
22	−2·04	168·05	256·74	·46	38·677	310·6369	2·3277
24	−2·05	123·99	197·41	·45	38·444	310·8084	2·3217
26	−2·07	79·94	138·10	·43	38·214	310·9798	2·3157
28	−2·08	35·89	78·79	+0·42	37·989	311·1512	+2·3097
30	−2·09	351·86	19·50	·40	37·768	311·3225	2·3036
Nov. 1	−2·10	307·84	320·22	·38	37·552	311·4938	2·2975
3	−2·12	263·83	260·95	·36	37·342	311·6650	2·2914
5	−2·13	219·83	201·69	·34	37·136	311·8362	2·2853
7	−2·14	175·84	142·43	+0·32	36·937	312·0074	+2·2792
9	−2·15	131·86	83·19	·30	36·743	312·1785	2·2731
11	−2·16	87·88	23·96	·28	36·556	312·3495	2·2669
13	−2·17	43·92	324·73	·26	36·376	312·5205	2·2607
15	−2·18	359·96	265·51	·24	36·202	312·6914	2·2545
17	−2·19	316·01	206·30	+0·22	36·036	312·8623	+2·2483
19	−2·20	272·07	147·10	·20	35·877	313·0331	2·2421
21	−2·21	228·14	87·90	·18	35·726	313·2039	2·2358
23	−2·22	184·21	28·71	·16	35·584	313·3746	2·2295
25	−2·23	140·28	329·53	·14	35·449	313·5453	2·2232
27	−2·24	96·36	270·35	+0·13	35·324	313·7160	+2·2169
29	−2·24	52·44	211·17	·11	35·207	313·8866	2·2106
Dec. 1	−2·25	8·53	152·00	·09	35·100	314·0572	2·2043
3	−2·26	324·62	92·83	·08	35·002	314·2277	2·1979
5	−2·26	280·72	33·66	·06	34·913	314·3981	2·1915
7	−2·27	236·81	334·49	+0·05	34·835	314·5685	+2·1851
9	−2·27	192·90	275·33	·04	34·766	314·7388	2·1787
11	−2·28	148·99	216·16	·03	34·707	314·9091	2·1723
13	−2·28	105·08	156·99	·02	34·659	315·0793	2·1659
15	−2·28	61·17	97·82	·01	34·621	315·2495	2·1594
17	−2·28	17·26	38·64	+0·01	34·593	315·4197	+2·1529

This ephemeris is a continuation of that for the preceding apparition of *Jupiter*, published in the May number of 1893, no alteration having been made in the assumed elements. But a column has been added giving the brightness of the planet expressed in star magnitudes, the brightness at mean opposition being assumed to be $-2^{m}\cdot233$ according to Professor G. Müller's determination, and the defect of illumination being allowed for by adding $+5$ log sec. $\frac{1}{2}(\Lambda - L)$.

The following is a list of Greenwich mean times when the zero-meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc:

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1894.	h m	h m	1894.	h m	h m
July 30	13 25·7	13 16·8	Aug. 19	15 44·2	19 49·0
	23 16·3	23 12·6	20	11 25·3	15 40·5
31	18 57·5	19 4·1	21	16 57·0	21 27·8
Aug. 1	14 38·7	14 55·7	22	12 38·2	17 19·2
2	0 29·3	0 51·4	23	18 9 8	23 6·5
	20 10·5	20 43·0	24	13 51·0	18 57·9
3	15 51·6	16 34·5	25	9 32·1	14 49·4
4	1 42·2	2 30·3		19 22·6	24 45·2
	21 23·4	22 21·8	26	15 3·7	20 36·6
5	17 4·6	18 13·4	27	10 44·8	16 28·1
6	12 45·7	14 4·9	28	16 16·5	22 15·3
	22 36·3	24 0·6	29	11 57·6	18 6·7
7	18 17·5	19 52·2	30	17 29·3	23 53·9
8	13 58·7	15 43·7	31	13 10·4	19 45·4
	23 49·3	25 39·5	Sept. 1	18 42·0	15 36·9
9	19 30·4	21 31·0	2	14 23·1	21 24·0
10	15 11·6	17 22·5	3	19 54·8	17 15·5
11	10 52·7	13 14·0	4	15 35·8	23 2·6
	20 43·3	23 9·8	5	11 16 9	18 54·1
12	16 24·5	19 1·3	6	16 48·5	14 45·5
13	12 5 6	14 52·8	7	12 29·6	10 36·9
	21 56·2	24 48·6		22 20·1	20 32·7
14	17 37·4	20 40·1	8	18 1·2	16 24·1
15	13 18·5	16 31·6	9	13 42·3	12 15·5
16	18 50·2	22 18·8		23 32·8	22 11·2
17	14 31·4	18 10·3	10	19 13·9	18 2·6
18	10 12·5	14 1·8	11	14 55·0	13 54·0
	20 3·1	23 57·5		24 45·5	23 49·8

	I. (877°·90)		II. (870°·27)			I. (877° 90)		II. (870°·27)	
1894.	h	m	h	m	1894.	h	m	h	m
Sept. 12	10	36·0	9	45·5	Oct. 9	12	9·4	17	0·6
	20	26·5	19	41·2	10	7	50·4	12	51·9
13	16	7·6	15	32·6		17	40·9	22	47·6
14	11	48·7	11	24·0	11	13	21·8	18	38·9
	21	39·2	21	19·7	12	9	2·8	14	30·2
15	17	20·2	17	11·1		18	53·3	24	25·9
16	13	1·3	13	2·5	13	14	34·2	10	21·5
	22	51·8	22	58·2		24	24·7	20	17·2
17	18	32·8	18	49·6	14	10	15·2	16	8·5
18	14	13·9	14	41·0	15	5	56·1	11	59·8
19	0	4·4	0	36·7		15	46·6	21	55·4
	19	45·4	20	28·1	16	11	27·5	17	46·7
20	15	26·5	16	19·5	17	7	8·5	13	38·0
21	11	7·5	12	10·9		16	59·0	23	33·7
	20	58·0	22	6·6	18	12	39·9	9	29·3
22	16	39·0	17	57·9		22	30·3	19	25·0
23	12	20·1	13	49·3	19	8	20·8	15	16·2
	22	10·6	23	45·0		18	11·3	25	11·9
24	17	51·6	19	36·4	20	13	52·2	11	7·5
25	13	32·6	15	27·8		23	42·7	21	3·2
26	19	4·1	21	14·8	21	9	33·1	6	58·8
27	14	45·1	17	6·2		19	23·6	16	54·4
28	10	26·1	12	57·5	22	15	4·5	12	45·7
	20	16·6	22	53·2		24	55·0	22	41·4
29	15	57·6	18	44·6	23	10	45·4	8	37·0
30	11	38·6	14	35·9		20	35·9	18	32·6
	21	29·1	24	31·6	24	6	26·4	14	23·9
Oct. 1	17	10·1	20	23·0		16	16·8	24	19·5
2	12	51·1	16	14·3	25	11	57·7	10	15·2
3	8	32·1	12	5·6		21	48·2	20	10·8
	18	22·6	22	1·3		17	29·1	16	2·1
4	14	3·6	17	52·6	27	13	10·0	11	53·3
5	9	44·6	13	44·0		23	0·4	21	48·9
	19	35·1	23	39·7	28	8	50·9	7	44·6
6	15	16·0	19	31·0		18	41·3	17	40·2
7	10	57·0	15	22·3	29	14	22·2	13	31·5
8	16	28·5	21	9·3		24	12·7	23	27·1

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1894.	h m	h m	1894.	h m	h m
Oct. 30	10 3·1	9 22·7	Nov. 18	6 43·0	10 0·7
	19 53·6	19 18·3		16 33·5	19 56·3
31	15 34·5	15 9·6	19	12 14·3	5 51·9
Nov. 1	11 15·4	11 0·8		22 4·7	15 47·5
	21 5·8	20 56·4	20	7 55·1	11 38·7
2	6 56·2	6 52·0		17 45·6	21 34·3
	16 46·7	16 47·7	21	13 26·4	7 29·9
3	12 27·6	12 38·9		23 16·8	17 25·5
	22 18·0	22 34·5	22	9 7·2	13 16·6
4	8 8·5	8 30·1		18 57·6	23 12·2
	17 58·9	18 25·8	23	4 48·0	9 7·8
5	13 39·8	14 17·0		14 38·5	19 3·4
	23 30·2	24 12·6	24	10 19·3	14 53·6
6	9 20·6	10 8·2		20 9·7	24 49·2
	19 11·1	20 3·8	25	6 0·1	10 45·8
7	5 1·5	5 59·4		15 50·5	20 41·4
	14 51·9	15 55·0	26	11 31·4	6 36·9
8	10 32·8	11 46·3		21 21·8	16 32·5
	20 23·3	21 41·9	27	7 12·2	12 23·7
9	6 13·7	7 37·5		17 2·6	22 19·3
	16 4·1	17 33·1	28	12 43·4	8 14·9
10	11 45·0	13 24·3		22 33·8	18 10·4
	21 35·1	23 19·9	29	8 14·2	14 1·6
11	7 25·8	9 15·5		18 4·6	23 57·2
	17 16·3	19 11·1	30	13 55·4	9 52·8
12	12 57·1	15 2·3		23 45·9	19 48·4
	22 47·5	24 57·9	Dec. 1	9 36·3	5 44·0
13	8 38·0	10 53·5		19 26·7	15 39·5
	18 28·4	20 49·1	2	5 17·1	11 30·7
14	14 9·2	6 44·7		15 7·5	21 26·3
	23 59·7	16 40·3	3	10 48·3	7 21·9
15	9 50·1	12 31·5		20 38·7	17 17·5
	19 40·5	22 27·1	4	6 29·1	13 8·6
16	5 30·9	8 22·7		16 19·5	23 4·2
	15 21·4	18 18·3	5	12 0·3	8 59·8
17	11 2·2	14 9·5		21 50·7	18 55·4
	20 52·6	24 5·1	6	7 41·1	4 50·9

1894.	I. (877°·90) h m	II. (870°·27) h m	1894.	I. (877°·90) h m	II. (870°·27) h m
	17 31·5	14 46·5	Dec. 12	11 17·2	9 44·7
Dec. 7	13 12·4	10 37·7		21 7·6	19 40·2
	23 2·8	20 33·3	13	6 58·0	5 35·8
8	8 53·2	6 28·8		16 48·4	15 31·4
	18 43·6	16 24·4	14	12 29·2	11 22·6
9	4 34·0	12 15·6		22 19·7	21 18·2
	14 24·4	22 11·2	15	8 10·1	7 13·7
10	10 5·2	8 6·8		18 0·5	17 9·2
	19 55·6	18 2·3	16	3 50·9	3 4·9
11	5 46·0	3 57·9		13 41·3	13 0·5
	15 36·4	13 53·5		23 31·7	22 56·1

(To be concluded in the supplementary number.)

Colonel Cooper's Observatory,
Markree, Collooney, Ireland.

Errata in Monthly Notices of the Royal Astronomical Society.

Vol. lii. p. 603, line 9 from top, *for* there *read* three.

„ liii. p. 71, *insert* 28 opposite to 16 31 47.

„ „ 73, line 29 from top, *for* 1375 *read* 1395.

„ „ 341, at foot of page, *for* +0 *read* +0·7.

„ „ 369, opposite to γ Virginis, *for* 12 56 *read* 12 36.

„ „ 370 „ „ „ 12 56 „ 12 36.

„ „ 371, opposite to Ref. No. 39, *delete* 1, 2.

„ „ 372 „ „ „ 64, *for* 2 41 E *read* 2 46 E.

„ „ 501, lowest line, *for* 1·3 *read* 61·3.

„ liv. p. 33, line 23 from top, *for* filing *read* filmy.

„ „ 123, line 16 from top, under Position Angle *insert* °, and *delete* " under No. of Obs.

„ „ 123, line 30 from top, *for* 206″·8 *read* 206°·8.

„ „ 238, line 20 from top, *for* places *read* phases.

J. T.

1894 *April* 29.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. SUPPLEMENTARY NUMBER. No. 9

Micrometrical Measures of the Diameters of Ceres, Pallas, and Vesta, made with the 36-inch Refractor of the Lick Observatory. By E. E. Barnard.

In *Astronomy and Astro-Physics* for May 1894 I have given the preliminary results of a series of measures of the diameters of three of the larger asteroids: *Ceres* (1), *Pallas* (2), *Vesta* ◯.

In the present paper the details of these measures are given. I regret that much bad weather in the spring of the year prevented as many observations of these objects as I had intended to make. It requires good atmospheric conditions to see and measure these small bodies well.

It was intended to include *Juno* (3) in the list, but though I examined it several times I could not get a satisfactory image to measure, from the disturbed condition of the atmosphere. A series of measures of the satellites of *Uranus* and of the Ball and Ring system of *Saturn* were being carried on at this time also, and took up the best nights. No actual measures of *Juno* were made therefore, but I hope to get good measures of it as soon as it is again favourably placed for observing. I hope also to continue the measures of *Ceres*, *Pallas*, and *Vesta*.

Of these last *Ceres* was measured on nine nights, and *Pallas* and *Vesta* on five nights each.

In my paper on this subject in *Astronomy and Astro-Physics* I called attention to the fact that previous measures and estimates had placed *Vesta* as the largest of the asteroids. The present measures give that position to *Ceres*. This has created some surprise, but the question is clearly settled, not only by the measures themselves, but by the fact that, though *Ceres* was more distant than *Pallas* or *Vesta*, it appeared some two times larger in the telescope than either of them. This was very evident, as they were examined on the same nights and at the same time

turning the telescope from one to the other. It should therefore be accepted without hesitation that *Ceres* is the largest of the asteroids.

Following are the measures which have been made with the filar micrometer of the 36-in. equatorial.

The first column gives the measured diameter; the second gives this quantity reduced to the mean distance of *Ceres* from the Sun, viz. 2·7673.

Ceres.

1894.		Obs'd.	At Δ 2·7673.	Deviation from Mean.
Mar.	11	0″·95	0″·55	−0″·13
	12	0·75	0·44	−0·02
	25	0·72	0·43	−0·01
Apr.	1	0·73	0·44	−0·02
	9	0·58	0·36	+0·06
	16	0·60	0·39	+0·03
	23	0·59	0·40	+0·02
	30	0·58	0·40	+0·02
May	7	0·47	0·34	+0·08
			0·417	

or at distance unity 1″·155.

Pallas.

1894.		Obs'd.	At Δ 2·7673.	Deviation from Mean.
Feb.	25	0″·75	0″·34	−0″·10
	26	0·59	0·26	−0·02
Mar.	11	0·44	0·21	+0·03
	12	0·46	0·21	+0·03
	25	0·40	0·20	+0·04
			0·244	

or at distance unity 0″·675.

Vesta.

1894.		Obs'd.	At Δ 2·7673.	Deviation from Mean.
Mar.	11	0″·38	0″·23	−0″·04
	12	0·46	0·22	−0·03
	25	0·33	0·16	+0·03
Apr.	1	0·39	0·20	−0·01
	9	0·29	0·15	+0·04
			0·194	

or at distance unity 0″·536.

These values of the diameters would be represented in miles by—

Ceres 520 miles
Pallas 304 „
Vesta 241 „

These differ somewhat—and in the case of *Ceres* considerably—from the preliminary values (from the first three observations) as given in the paper in *Astronomy and Astro-Physics* referred to, viz.

Ceres 599 miles (0″·481 at Δ 2·7673 or 1″·330 at Δ 1)
Pallas 273 „ (0·211 „ „ 0·605 „)
Vesta 237 „ (0·191 „ „ 0·527 „)

The first few measures of *Ceres* were doubtless somewhat too large, as is shown in the series for that planet. We must remember, however, that the entire quantities themselves that are measured are very small in consideration of the great distance of the objects from us, a tenth of a second at the mean distance of *Ceres* being represented by 125 miles.

I have refrained from giving the probable errors of these results, for such seldom mean anything except to show the accordance of the measures among themselves. I have instead inserted a column of "deviations from the mean."

I think another year's measures will give fairly satisfactory diameters to these three asteroids—better, I believe, than can be obtained by any other method.

Mr. E. J. Stone's values for the diameters of these asteroids, viz.

Ceres 196 miles
Pallas 171 „
Vesta 214 „

were deduced from measures of *Ceres* and *Pallas* by Herschel and Lamont, whose instruments were certainly inadequate to deal with such quantities as the diameters of the minor planets.

Mount Hamilton:
1894 *August* 28.

Note on Professor Turner's Paper on the Reduction of Measures of Photographic Plates (*Monthly Notices*, vol. liv., 1893 November). By F. W. Dyson, M.A.

In Note IV. of this paper several small errors are made, which can easily be corrected in the margin, but which deserve to be noticed on account of the importance of the subject.

On p. 23, after "The coefficient of y_1 in the numerator x_2 is"

read $(-\sec P_2 \sin \overline{A_1 - A_2})/D$

$$= -X_{12} \cot P_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

After "The coefficient of x_1 in the numerator of y_2 is"

$$\textit{read } (\sec P_1 \sin \overline{A_1 - A_2})/D$$
$$= -X_{21} \cot P_2 . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

These corrections should be carried through into formulæ (18) on p. 24. In the first line,

$$\textit{instead of } y_1 . X_{21} \cot P_2$$
$$\textit{read } -y_1 X_{12} \cot P_1,$$

and in the second line,

$$\textit{instead of } x_1 X_{12} \cot P_1$$
$$\textit{read } -x_1 X_{21} \cot P_2.$$

These rigorous formulæ ought to be used instead of the approximate ones at the bottom of the page, for although the coefficients of x_1 in the first line and y_1 in the second line only differ from unity by quantities of the second order, yet these differences are of the same order of magnitude as the constants a, b, &c., which would be obtained by comparison of the measures of two actual photographs.

These coefficients of x_1 and y_1 are found to be

$$1 - \tfrac{1}{2}(X_{12}^2 \cot^2 P_1 - Y_{12}^2).$$

and

$$1 - \tfrac{1}{2}(\cot P_1 \cot P_2 - 1) X_{12} X_{21}$$

to the second order, but there is no objection to computing the coefficients directly as they are given in formulæ (18), as Y_{12} approximates to $-Y_{21}$ in the general case (not to Y_{21}, as in the particular case given where the terms of the first order vanish), and consequently the fractions do not take an indeterminate form.

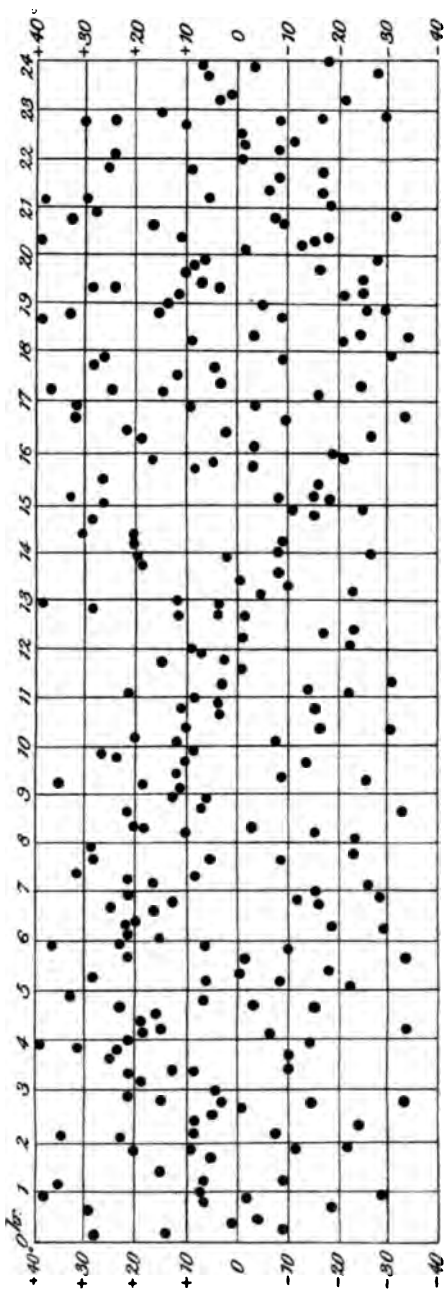
One other point which may be noticed refers to the paragraph at the end of Professor Turner's paper. Although

$$a_{1n} = a_{12} + a_{23} + \ldots + a_{n-1,n}.$$
$$c_{1n} \textit{ does not} = c_{12} + c_{23} + \ldots + c_{\overline{n-1},n}.$$

but differs from this by the sum of a number of terms of the form $a_{23} X_{12}$, $b_{23} Y_{12}$. The corrected form of this relation is rather cumbrous set down in a formula, but in practice would be quite easy to apply.

Blackheath:
1894 *September* 20.

[Mr. Dyson allows me to state here that I am much obliged to him for correcting these errors, the occurrence of which will be understood, and perhaps pardoned by those who have experienced the difficulties of breaking fresh ground.—H. H. T.]



Stars situated between + 40° and -35° dec. whose apparent places are given in the Nautical Almanac 1898.

Note on Stars suitable for the Determination of Clock errors.
By A. M. W. Downing, M.A., D.Sc.

The total number of stars whose apparent places are given in the revised list contained in the *Nautical Almanac* for 1898 is 404, including sixteen close polar stars. It may, at the present time, be of interest to show (with special reference to Mr. Stone's paper in the last number of the *Monthly Notices*) the distribution of the *Nautical Almanac* stars situated between + 40° and — 35° dec., and which, therefore, with few exceptions, are suitable for the determination of clock-errors.

The diagram (Plate 13) shows the general distribution of the stars referred to, including *all* the Greenwich clock-stars and sixty additional stars. The adopted places of many of these latter stars are, necessarily, at present of considerably inferior accuracy to those of the former. The names, magnitudes (taken from the *Harvard Photometry*, or the *Uranometria Argentina*), and approximate mean places for 1898 of the sixty additional stars are appended.

It will be seen that the distribution is not altogether an ideal one, but may, perhaps, be considered fairly satisfactory, bearing in mind the various claims that had to be adjusted, as equitably as was practicable, in making the selection for such a work as the *Nautical Almanac*.

Although I had not the advantage of seeing Mr. Stone's list of proposed additions to the Greenwich clock-stars in time to make any use of it in revising the *Nautical Almanac* stars, it will be observed that fourteen of these proposed additions are in the *Nautical Almanac* list.

I may take the opportunity of stating that arrangements have been made with Professor Tietjen for the exchange of certain portions of the calculations made for the German and English Ephemerides, in extension of the system of co-operation already established with Professor Newcomb. The computing energy thus set free cannot, perhaps, be better utilised than by still further enlarging the list of stars whose apparent places are given in the *Nautical Almanac*, and thus improving the general distribution of those situated in the neighbourhood of the equator.

It may not be out of place to remark that the time seems almost ripe for the realisation of a project that has long been a desideratum in practical astronomy—*i.e.* the adoption of a uniform system of clock-stars in the astronomical ephemerides of different nations. The advantages of such a step are sufficiently obvious, and have recently been pointed out by Professor Hall (*Astronomical Journal*, No. 321). I trust that, before many years have passed, it may be possible to carry out this much-needed reform.

Stars (other than Greenwich Clock-stars) whose apparent places are given in the Nautical Almanac 1898.

Star.	Mag.	Approximate R.A. h m s	Dec. ° ′
α Sculptoris	4·1	0 53 41	−29 55
ζ Ceti	3·8	1 46 25	−10 50
υ Ceti	3·8	1 55 12	−21 34
β Trianguli	3·1	2 3 28	+34 30
κ Fornacis	5·4	2 17 53	−24 17
π Ceti	4·3	2 39 16	−14 17
β Fornacis	4·7	2 44 49	−32 50
ζ Persei	3·1	3 47 43	+31 35
ε Persei	3·0	3 51 0	+39 43
υ^4 Eridani	3·3	4 14 2	−34 3
53 Eridani	3·9	4 33 30	−14 30
π^1 Orionis	3·3	4 44 18	+ 6 47
γ Orionis	1·9	5 19 40	+ 6 15
ζ Tauri	3·0	5 31 33	+21 5
θ Aurigæ	2·7	5 52 46	+37 12
ζ Canis Maj.	3·0	6 16 24	−30 1
ε Geminorum	3·2	6 37 39	+25 14
α Canis Maj.	−1·4	6 40 39	−16 35
δ Canis Maj.	1·9	7 4 15	−26 14
γ Monocerotis	4·2	7 36 22	− 9 19
20 Puppis	5·1	8 8 39	−15 29
30 Monocerotis	3·9	8 20 34	− 3 34
α Muli	3·6	8 39 30	−32 49
ζ Hydræ	3·3	8 50 0	+ 6 20
α Lyncis	3·4	9 14 51	+34 49
h Muli	4·9	9 16 58	−25 32
κ Hydræ	4·9	9 35 25	−13 52
22 Sextantis	5·4	10 12 34	− 7 34
α Antliæ	4·5	10 22 29	−30 33
ν Hydræ	3·3	10 44 36	−15 40
β Crateris	4·4	11 6 38	−22 16
ξ Hydræ	3·8	11 27 59	−31 18
γ Virginis	2·8	12 36 29	− 0 53
α Canum Ven.	3·0	12 51 15	+38 52
γ Hydræ	3·4	13 13 22	−22 38
π Hydræ	3·5	14 0 34	−26 11

Star.	Mag.	Approximate R.A. h m s	Dec. ° ′
20 Libræ	3·2	14 58 6	−24 53
δ Boötis	3·5	15 11 23	+33 42
μ Serpentis	3·5	15 44 18	− 3 7
δ Scorpii	2·5	15 54 18	−22 20
β Herculis	2·8	16 25 50	+21 43
ε Scorpii	2·2	16 43 33	−34 6
30 Ophiuchi	5·0	16 55 41	− 4 4
δ Herculis	3·3	17 10 50	+24 58
π Herculis	3·4	17 11 30	+36 55
ν Ophiuchi	3·5	17 53 25	− 9 46
γ^2 Sagittarii	3·0	17 59 15	−30 26
ε Sagittarii	2·1	18 17 24	−34 26
σ Sagittarii	2·3	18 48 56	−26 25
λ Aquilæ	3·6	19 0 50	− 5 2
π Sagittarii	3·1	19 3 42	−21 11
β Cygni	3·1	19 26 36	+27 45
γ Cygni	2·3	20 18 34	+39 56
ε Cygni	2·7	20 42 5	+33 35
1 Piscis Aust.	5·0	20 55 2	−32 39
61 Cygni	5·1	21 2 20	+38 15
η Pegasi	3·1	22 38 13	+29 41
δ Aquarii	3·4	22 49 14	−16 22
c^2 Aquarii	3·6	23 4 0	−21 44
27 Piscium	5·0	23 53 27	− 4 7

Nautical Almanac Office:
1894 *October* 3.

On the Proper Motions of Groombridge 1172, *W.B.* (2) *XII.* 740–1, W.B. *XII.* 632. By A. C. D. Crommelin.

These stars have all been used as comet comparison stars at Greenwich in the last twelve months, and on comparing recent Greenwich observations with the older ones they appear to have sensible proper motions. Struve's precessions have been used throughout in bringing the places up to 1894·0. Two cases where the exact epoch of the original observation could not be found are indicated with an asterisk.

Groombridge 1772, *mag.* 6·5.

This star was used in a comparison with Comet *b* 1894 (Gale). The places given are reduced to 1894·0 without proper motion.

Catalogue.	R.A. 1894·0.	N.P.D. 1894·0.	Epoch.	No. of Obs.
	h m s	° ′ ″		
Lalande 21652	11 16 56·241	49 14 33·50	1793·3	1
Groombridge 1772	56·049	36·30	1811·3	5
W.B. (2) XI. 264	56·248	(24·20)	1831·24	1
Rumker	55·947	35·35	1840*	1
Radcliffe	55·950	34·98	1845·9	5 R.A.
			1847·1	5 N.P.D.
Paris III.	55·473	35·44	1881·3	3 R.A., 2 N.P.D.
Greenwich 1887	55·613	36·37	1887·37	1
,, 1888	55·564	37·12	1888·34	1
,, 1890	55·496	37·21	1890·28	1

The N.P.D. of *W.B.* (2) appears to be 10″ too small. A proper motion of $-0^{s}\cdot0084$, $+0''\cdot025$ represents these as follows:—

Catalogue.	R.A. 1894·0.	N.P.D. 1894·0.
	h m s	° ′ ″
Lalande	11 16 55·395	49 14 36·02
Groombridge	55·355	38·37
W.B. (2)	55·721	(35·77) (corrected by + 10″)
Rumker	55·493	36·70
Radcliffe	55·546	36·15
Paris (III.)	55·367	35·76
Greenwich 1887	55·557	36·54
,, 1888	55·516	37·26
, 1890	55·465	37·30
Weighted Mean	11 16 55·461	49 14 36·87

W.B. (2) XII. 740–1, *mag.* 8·7.

There is only a presumption of proper motion in this case, since no observations have been found intermediate between the two by Bessel and the recent ones at Greenwich. The star was used for Comet *c* 1893 (Brooks) on 1893 October 25.

Catalogue.	R.A. 1894·0.	N.P.D. 1894·0.	Epoch.	No. of Obs.
	h m s	° ′ ″		
W. B. (2) XII. 740	12 37 3·044	71 8 32·50	1826·35	1
„ „ 741	3·284	29·90	„	1
Greenwich 1894	2·783	23·31	1894·23	3

The indicated proper motion is $-0^s\cdot0057$, $-0''\cdot116$.

W.B. XII. 632, *mag.* 8·5.

This star was used for the same comet on 1893 October 18. There seems no doubt of its having a large proper motion in R.A.

Catalogue.	R.A. 1894·0.	N.P.D. 1894·0.	Epoch.	No. of Obs.
	h m s	° ′ ″		
Lalande 23763	12 39 37·107	75 55 (33·40)	1795·2	1
W.B. XII. 632	(27·656)	43·47	1825*	1
Yarnall	36·008	44·43	1864·8 1866·3	9 R.A. 2 N.P.D.
Greenwich 1894	35·410	45·07	1894·23	3

The N.P.D. in *Lalande* and the R.A. in *W.B.* seem too small by 10″ and 10^s respectively. A proper motion of $-0^s\cdot0185$, $+0''\cdot021$ represents the above places as follows:—

Catalogue.	R.A. 1894·0.	N.P.D. 1894·0.	
	h m s	° ′ ″	
Lalande	12 39 35·279	75 55 (45·47)	(corrected by +10″)
W.B.	(36·379)	44·92	(R.A. corrected by $+10^s$)
Yarnall	35·468	45·01	
Greenwich	35·414	45·07	

Weighted mean (rejecting *W.B.* in R.A.) $12^h\ 39^m\ 35^s\cdot441$, $75°\ 55'\ 45''\cdot09$.

The two stars *W.B.* (2) X.417–8, *W.B.* (2) X.480, mags. 8·8, 9·0 repectively, whose probable proper motion was alluded to by Sir R. S. Ball (*Monthly Notices*, liv. 8, p. 555), occur in the Leiden zones. The places reduced to 1894·0 are as follows:—

Catalogue.	R.A. 1894·0. h m s	N.P.D. 1894·0. ° ′ ″	
W.B. (2) X. 417	10 23 22·51	57 27 8·6	1830·27
„ „ 418	22·85	6·3	1831·27
Leiden Z. 287	21·89	5·4	1873·22
„ 288	21·97	4·9	1873·22
W. B. (2) X. 480	10 26 28·53	57 29 53·0	1830·27
Leiden Z. 169	29·22	52·0	1872·19
„ 281	29·31	51·3	1873·19

There seems to be a sensible proper motion in R.A. in each case, the values indicated being $-0^s\cdot0177$, $+0^s\cdot0173$ respectively.

Observations of Comet b 1894 (*Gale*) *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the Fast, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55. On July 11 the observations were made with the 28-inch equatorial.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1894. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
June 7 12 13 45	B.	+2 44·14	0·00	9·6867	− 0 40·8	0·0	0·7171	3	11 19 41·43	49 13 50·3	*a*
21 10 59 4	„	−0 0·45	0·00	9·6901	− 1 8·6	0·0	0·6255	3	...	...	*b*
22 11 28 6	A.C.	+1 58·48	0·00	9·6999	− 5 45·8	−0·1	0·6735	2	...	...	*b*
22 11 28 6	„	+1 16·28	0·00	9·6999	+ 7 20·4	+0·1	0·6735	2	...	...	*c*
24 11 8 27	H.	+1 24·80	0·00	9·6971	+ 5 41·7	+0·1	0·6480	4	11 56 24·45	46 54 52·6	*d*
24 11 33 29	„	−0 31·94	0·00	9·7021	−10 10·5	−0·2	0·6866	4	...	...	*e*
28 11 19 3	„	+2 19·88	0·00	9·6994	− 3 31·7	−0·0	0·6521	6	12 4 4·27	46 41 19·9	*f*
28 11 19 3	„	+1 25·83	0·00	9·6994	− 1 9·5	+0·0	0·6521	6	12 4 4·54	46 41 19·6	*g*
29 10 44 43	C.D.	−0 38·00	0·00	9·6941	+ 9 22·9	0·0	0·6233	3	12 5 59·12	46 38 41·7	*h*
29 10 51 23	H.F.	−0 38·42	0·00	9·6967	+ 9 36·1	+0·1	0·6344	3	12 5 58·70	46 38 55·0	*h*
30 11 20 25	A.C.	+1 15·66	0·00	9·7041	+ 7 6·4	+0·1	0·6831	4	12 7 52·76	46 36 25·3	*h*

Greenwich Mean Solar Time.					Observer.	⌀ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	⌀ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1894	d	h	m	s		m s	s		″	″			h m s	° ′ ″	
July	2	10	57	10	H.	−0 34·37	0·00	9·7013	− 3 58·3	0·0	0·6533	6	12 11 32·14	46 32 52·4	*i*
	3	11	25	23	A.C.	+1 18·63	0·00	9·7053	− 5 46·9	−0·1	0·6990	3	12 13 25·12	46 31 3·7	*i*
	7	10	46	3	,,	+1 21·45	0·00	9·7019	+ 7 34·3	0·0	0·6514	1	12 20 34·44	46 27 0·0	*k*
	7	10	48	56	,,	+0 52 31	0·00	9·7026	− 6 10·9	−0·1	0·6561	1	12 20 39·78	46 27 12·3	*l*
	11	11	20	57	M.	+0 47·32	0·00	9·7051	+ 1 5·9	0·0	0·7163	7	...	...	*m*
	11	11	21	26	,,	−0 25·76	0·00	9·7051	+ 2 33·3	0·0	0·7169	6	...	...	*n*
	11	11	30	42	,,	+1 24·91	0·00	9·7040	+ 2 50·0	0·0	0·7291	1	...	...	*o*
	11	11	30	42	,,	+1 7·88	0·00	9·7040	+ 3 11·7	0·0	0·7291	1	...	...	*p*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires, and for the motion of the comet.

June 21.—Very difficult and doubtful observations; sky very hazy; observations impaired also by glow from great fire in Finsbury.

June 22.—Comet faint; cloudy.

June 24.—Comet very faint and diffused.

June 28.—Comet exceedingly faint.

July 2.—Comet excessively faint; very hard to see.

July 3.—Comet very faint and ill-defined.

July 7.—The comet was excessively faint; observations rough. The observations of R.A. are very discordant, but no mistake has been detected.

July 11.—The comet was exceedingly diffused and faint; no shape could be detected, certainly no nucleus. Generally it could be seen only by partly averted vision.

The initials M., H., A.C., B., H.F., C.D., are those of Mr. Maunder, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Furner and Mr. Davidson respectively.

Comparison Stars.

Star's Name.	R.A., 1894·0 h m s	N.P.D., 1894·0 ° ′ ″	Authority.
a. Groombridge, 1772	11 16 55·51	49 14 37·0	Greenwich Observations, 1887, -88, -90, with P.M. -0″·0084 +0″·025.
b. B.D. + 43°, 2167	11 50 29·1	47 8·2	Bonn Observations, vol. v.
c. B.D. + 43°, 2169	11 51 9·5	46 55·0	„ „
d. B.D. + 43°, 2174	11 54 57·86	46 49 16·3	„ „ vi.
e. B.D. + 43°, 2181	11 56 59·5	47 4·3	„ „ v.
f. W.B. (2) XI., 1183	12 1 42·63	46 44 56·9	Weisse's Bessel (2).
g. B.D. + 43°, 2191	12 2 36·94	46 42 34·3	Equatorial Comparisons with star *f* at Cincinnati (*Ast. Journ.* 323)
h. W.B. (2) XII., 95	12 6 35·34	46 29 24·0	Weisse's Bessel (2).
i. W.B. (2) XII., 198	12 12 4·75	46 36 55·7	„ „
k. W.B. (2) XII., 358	12 19 11·28	46 19 30·4	Pulkova Catalogue, 1875.
l. W.B. (2) XII., 373	12 19 45·76	46 33 28·0	Lalande and Weisse's Bessel (2).
m. B.D. + 43°, 2236	12 27 2·8	46 25·0	Bonn Observations, vol. v.
n. Anonymous	12 28 15	46 23	Difference from star *m*.
o. „	12 26 27	46 23	„ „ „
p. „	12 26 44	46 23	„ „

Royal Observatory, Greenwich:
1894 *September* 11.

Observations of Comet b 1894 (*Gale*).

(*Communicated by Sir R. S. Ball.*)

The Comet (Gale) was again observed here on the night of June 11. The place obtained from the observations is—

G.M.T. corrected for Aberrn.	Geoc. R.A.	Geoc. Decl.
1894.	h m s	° ′ ″
June 11·49565	11 29 14·77	41 36 3·2

Comparison Star. R.A. 1894·0.	Decl. 1894·0.	Authority.	No. of Comparisons.
h m s	° ′ ″		
11 33 19·40	41 43 56·8	W.B. 11^h 602	10

From this observation, combined with those made here on May 4 and May 23, Mr. Graham obtained the following parabolic elements of the orbit:—

Per. Pass. 1894 *April* 13·53750 *Greenwich M.T.*

$\pi - \Omega$	324 19 21·92	1894·0
Ω	206 20 55·81	
i.	87 3 11·22	
log q	9·9928092	

Motion direct.

The difference between the observed and calculated places on May 23 is—

	In R.A.	In Decl.
	s	″
O − C	+0·12	−1·1

The Observatory, Cambridge:
1894 *June* 27.

Observations of Comet b 1894 (*Gale*) *made at the Royal Observatory, Cape of Good Hope.*

(*Communicated by David Gill, LL.D., F.R.S., H.M. Astronomer at the Cape.*)

1894.	Cape Mean Time.	Comet−Star. Δ α.	Δ δ.	No. of Comps.	Obser-ver.	Comet's App. R.A.	Log ($p \times \Delta$).	Comet's App. Dec.	Log ($p \times \Delta$).	Reduction to App. Place.		Comp. Star No.
	h m s	m s	″			h m s		° ′ ″		s	″	
Apr. 11	7 16 46·1	−0 55·79	−5 7·0	4·4	F.	3 30 27·31	9·919	−54 57 5·1	0·151*n*	−1·07	−1·9	1
12	7 46 7·1	−1 47·19	−3 42·0	12·8	F.	3 40 3·41	9·924	−54 40 13·4	0·328*n*	−1·07	−2·1	2
13	7 22 27·2	−0 29·64	+5 35·2	8·8	F.	3 49 51·57	9·910	−54 19 39·4	0·120*n*	−1·07	−2·4	3
17	7 7 5·3	−0 54·83	−2 42·3	8 8	F.	4 35 30·92	9·853	−51 55 36·6	9·654*n*	−0·99	−3·6	4
23	7 2 53·5	−0 30·02	+0 6·4	12·8	F.	5 59 19·05	9·695	−43 1 22·7	9·308*n*	−0·60	−6·4	5
24	8 4 59·6	+1 46·38	−0 8·2	12·8	F.	6 14 51·49	9·748	−40 30 14·6	0 139*n*	−0·51	−6·6	6
25	7 43 58·5	−2 24·24	−2 13·2	12·8	F.	6 29 30·01	9·691	−37 48 32·5	0·046*n*	−0·39	−7·0	7
26	8 32 43·6	+1 15·18	−1 12 3	12·8	F.	6 44 45·00	9·720	−34 39 00·0	0·316*n*	−0·29	−7·0	8
27	7 41 7·7	−2 16·16	−3 10·8	12·8	F.	6 58 41·54	9·618	−31 25 15·0	0·192*n*	−0·17	−7·1	9
28	7 40 56·1	−1 51·54	−2 2·6	12·8	F.	7 12 50·60	9·583	−27 47 49·4	0·274*n*	−0·06	−6·9	10
30	7 42 15·0	+0 28·26	−0 31·1	12·8	F.	7 39 50·45	9·518	−19 55 0·1	0·430*n*	+0·16	−6·0	11
May 1	7 50 6·4	+1 14·63	−2 34·8	12·8	F.	7 52 36·45	9·507	−15 46 27·0	0·503*n*	+0·26	−5·3	12
2	7 50 41·0	−1 14·99	−1 47·0	12·8	F.	...	9·480	...	0·560*n*	+0·37	−4·7	13
3	7 36 39·0	−1 34·18	+4 50·1	6·4	F.	...	9·415	...	0·607*n*	+0·47	−4·0	14
5	7 38 16·5	−2 22 80	−0 13·6	12·8	F.	...	9·373	...	0 693*n*	+0·66	−2·2	15

The observations were made with the filar micrometer and the 7-inch equatorial by Mr. W. H. Finlay. They are corrected for refraction.

Notes.

April 12.—Moonlight; comet bright and large; no well-defined condensation for observation.
April 24.—The comet showed a short faint tail.
May 1.—Definition extremely bad.

Comet b 1894 (*Gale*).

Assumed Mean Places of the Comparison Stars.

Comparison Star No.	R.A. 1894·0. h m s	Dec. 1894·0. ° ′ ″	Authority.
1	3 31 24·17	−54 51 56·2	Cape (1880), No. 1492
2	3 41 51·67	−54 36 29·3	„ „ 1586
3	3 50 22·28	−54 25 12·2	8½ mag. = Cape (1880), No. 1705 − 6ᵐ 56ˢ·05 + 2′ 27″·1
4	4 36 26·74	−51 52 50·7	Cape (1880), No. 2013
5	5 59 49·67	−43 1 22·7	9½ mag. = Cape (1880), No. 2750 + 2ᵐ 12ˢ·93 − 9′ 2″·5
6	6 13 5·62	−40 29 59·8	9½ mag. = Cape (1880), No. 2840 + 6ᵐ 20ˢ·60 − 9′ 55″·7
			and = „ „ 2904 − 1ᵐ 11ˢ·00 + 7′ 4″·0
7	6 31 54·64	−37 46 12·3	C.G.A. 8103
8	6 43 29·7	−34 38 (0)	Cape Photo. DM.
9	7 0 57 87	−31 21 57·1	C.G.A. 8941
10	7 14 42·20	−27 45 39·9	10 mag. = Cape (1880), No. 3534 + 2ᵐ 22ˢ 10 − 4′ 1″ 1
11	7 39 22·03	−19 54 23·0	B.D. − 19·2035 = {O.A. 6080 / Paris 9604} − 5ᵐ 44ˢ·00 + 1′ 47″·8
			and = O.A. 6047 − 4ᵐ 24ˢ·40 + 4′ 21″·7
12	7 51 21·56	−15 43 46·9	O.A. 6219. Also = O.A. 6199 + 0ᵐ 46ˢ·72 − 4′ 51″·5
13	8 6	−11 36	B.D. − 11·2267
14	8 16	− 7 43	B.D. − 7·2453
15	8 40	+ 0 10	B.D. + 0·2380

Data for Computing the Positions of the Satellites of Jupiter 1894–95. By A. Marth.

The following data for computing the places of the satellites for the present apparition of *Jupiter* are a continuation of those for the three preceding apparitions published in the *Monthly Notices*. The motions of the longitudes and of the arguments, and the inequalities corresponding to the arguments, are to be found on pp. 524–539 of vol. li.

The last eclipses of Sat. IV., which occurred 1892 April 16, $13^{h}{\cdot}0$ Gr., and May 3, $7^{h}{\cdot}2$ Gr. (the latter not given by the tables), were not observable on account of *Jupiter* being too near the Sun. The next cycle of eclipses begins in 1895 February (the satellite remaining outside the shadow-cone at the nearest approach on January 17), but it is doubtful whether, on February 2 at $20^{h}\ 2^{m}$ Gr., the satellite will really be within the shadow-cone or merely skirt it (*v. Monthly Notices*, vol. xliv., p. 243), and Australian observers must be on the watch to remove the doubt. On February 19 observers in America will be favoured with the opportunity of observing a real eclipse, but of considerably shorter duration than that derived from the tables, and the next eclipse, on March 8, will be observable in Europe and Africa. Of course, care must be taken that the times noted at the satellite's disappearance and reappearance refer to corresponding phases.

An ephemeris of the fifth satellite is given in No. 3253 of the *Astr. Nachrichten.*

First Satellite.

Greenwich Noon. 1894–95.	Longitude. $l_1 - O$	S_1	Arguments. α_1	β_1	γ_1	δ_1	ϵ_1
	°	°					
July 30	298·8751	+·0039	·9821	·496	·748	·239	·234
Aug. 9	173·7647	39	·6551	·914	·396	·891	·259
19	48·6542	38	·3282	·332	·045	·543	·284
29	283·5438	37	·0012	·750	·693	·196	·308
Sept. 8	158·4334	37	·6742	·169	·341	·848	·333
18	33·3229	36	·3472	·587	·990	·500	·358
28	268·2125	+·0036	·0202	·005	·638	·152	·382
Oct. 8	143·1020	35	·6932	·423	·286	·805	·407
18	17·9916	34	·3662	·842	·935	·457	·432
28	252·8812	34	·0392	·260	·583	·109	·456
Nov. 7	127·7707	33	·7123	·678	·231	·762	·481
17	2·6603	32	·3853	·096	·879	·414	·506
27	237·5498	+·0032	·0583	·515	·528	·066	·530
Dec. 7	112·4394	31	·7313	·933	·176	·718	·555
17	347·3290	30	·4043	·351	·824	·371	·580
27	222·2185	30	·0773	·769	·473	·023	·605
Jan. 6	97·1081	29	·7503	·188	·121	·675	·629
16	331·9976	29	·4233	·606	·769	·327	·654
26	206·8872	+·0028	·0964	·024	·418	·980	·679
Feb. 5	81·7768	27	·7694	·442	·066	·632	·703
15	316·6663	27	·4424	·861	·714	·284	·728
25	191·5559	26	·1154	·279	·363	·937	·753
Mar. 7	66·4454	25	·7884	·697	·011	·589	·777
17	301·3350	25	·4614	·115	·659	·241	·802
27	176·2246	+·0024	·1344	·534	·308	·893	·827
Apr. 6	51·1141	23	·8075	·952	·956	·546	·851
16	286·0037	23	·4805	·370	·604	·198	·876
26	160·8932	22	·1535	·788	·252	·850	·901
May 6	35·7828	21	·8265	·207	·901	·502	·925
16	270·6724	21	·4995	·625	·549	·155	·950
26	145·5619	+·0020	·1725	·043	·198	·807	·975

	Inclination. γ_1	Node. $O - \Gamma_1$		Inclination. γ_1	Node. $O - \Gamma_1$
	°	°		°	°
1894 July 30	0·0091	148·0	1894 Dec. 27	0·0093	156·2
Aug. 29	91	149·6	1895 Jan. 26	93	157·8
Sept. 28	91	151·3	Feb. 25	93	159·4
Oct. 28	92	152·9	Mar. 27	93	161·0
Nov. 27	92	154·6	Apr. 26	94	162·6
Dec. 27	0·0093	156·2	May 26	0·0094	164·2

First Satellite.

Greenwich Noon. 1894–95.	Arguments. ζ_1	η_1	θ_1
July 30	·903	·243	·065
Aug. 9	·925	·264	·086
19	·947	·285	·106
29	·969	·306	·127
Sept. 8	·990	·326	·148
18	·012	·347	·168
28	·034	·368	·189
Oct. 8	·056	·388	·209
18	·077	·409	·230
28	·099	·430	·251
Nov. 7	·121	·451	·271
17	·143	·471	·292
27	·164	·492	·312
Dec. 7	·186	·513	·333
17	·208	·534	·354
27	·230	·554	·374
Jan. 6	·251	·575	·395
16	·273	·596	·415
26	·295	·617	·436
Feb. 5	·317	·637	·457
15	·338	·658	·477
25	·360	·679	·498
Mar. 7	·382	·700	·518
17	·404	·720	·539
27	·425	·741	·560
Apr. 6	·447	·762	·580
16	·469	·783	·601
26	·491	·803	·621
May 6	·512	·824	·642
16	·534	·845	·663
26	·556	·866	·683

Second Satellite.

Longitude. $l_2 - O$	S_2	Arguments. α_2	β_2
° 122·0915	° −·0067	·99107	·496
55·8388	68	·82757	·914
349·5860	69	·66408	·332
283·3333	70	·50058	·750
217 0805	71	·33709	·169
150·8278	72	·17360	·587
84·5750	−·0073	·01010	·005
18·3223	74	·84661	·423
312·0696	74	·68312	·842
245·8168	75	·51962	·260
179·5641	76	·35613	·678
113·3113	77	·19264	·096
47·0586	−·0077	·02914	·515
340·8058	78	·86565	·933
274·5531	79	·70216	·351
208·3004	79	·53866	·769
142·0476	80	·37517	·188
75·7949	81	·21167	·606
9·5421	−·0081	·04818	·024
303·2894	82	·88469	·442
237·0366	82	·72119	·861
170·7839	83	·55770	·279
104·5311	83	·39421	·697
38·2784	84	·23071	·115
332·0257	−·0084	·06722	·534
265·7729	85	·90373	·952
199·5202	85	·74023	·370
133·2674	86	·57674	·788
67·0147	86	·41324	·207
0·7619	86	·24975	·625
294·5092	−·0087	·08626	·043

	Inclination. γ_2	Node. $O - \Gamma_2$
	°	°
1894 July 30	0·4845	155 37
Aug. 29	·4844	156·35
Sept. 28	·4843	157·33
Oct. 28	·4841	158·31
Nov. 27	·4840	159·28
Dec. 27	0·4839	160·26

Second Satellite.

Greenwich Noon. 1894-95.	Arguments. γ_2	δ_2	ϵ_2	ζ_2	η_2	θ_2	ι_2	κ_2	λ_2
July 30	·088	·748	·926	·903	·743	·565	·734	·234	·056
Aug. 9	·903	·564	·742	·925	·764	·586	·759	·092	·913
19	·717	·379	·558	·947	·785	·606	·784	·949	·771
29	·532	·195	·374	·969	·806	·627	·808	·806	·628
Sept. 8	·347	·011	·189	·990	·826	·648	·833	·663	·485
18	·162	·827	·005	·012	·847	·668	·858	·521	·342
28	·976	·642	·821	·034	·868	·689	·882	·378	·199
Oct. 8	·791	·458	·637	·056	·888	·709	·907	·235	·056
18	·606	·274	·453	·077	·909	·730	·932	·092	·913
28	·421	·090	·269	·099	·930	·751	·956	·950	·770
Nov. 7	·235	·905	·085	·121	·951	·771	·981	·807	·627
17	·050	·721	·901	·143	·971	·792	·006	·664	·484
27	·865	·537	·717	·164	·992	·812	·030	·521	·342
Dec. 7	·680	·353	·533	·186	·013	·833	·055	·379	·199
17	·494	·168	·349	·208	·034	·854	·080	·236	·056
27	·309	·984	·164	·230	·054	·874	·105	·093	·913
Jan. 6	·124	·800	·980	·251	·075	·895	·129	·950	·770
16	·939	·616	·796	·273	·096	·915	·154	·808	·627
26	·753	·432	·612	·295	·117	·936	·179	·665	·484
Feb. 5	·568	·247	·428	·317	·137	·957	·203	·522	·341
15	·383	·063	·244	·338	·158	·977	·228	·379	·198
25	·198	·879	·060	·360	·179	998	·253	·237	·055
Mar. 7	·012	·695	·876	·382	·200	·018	·277	·094	·913
17	·827	·510	·692	·404	·220	·039	·302	·951	·770
27	·642	·326	·508	·425	·241	·060	·327	·808	·627
Apr. 6	·457	·142	·324	·447	·262	·080	·351	·666	·484
16	·271	·958	·139	·469	·283	·101	·376	·523	·341
26	·086	·773	·955	·491	·303	·121	·401	·380	·198
May 6	·901	·589	·771	·512	·324	·142	·425	·237	·055
16	·716	·405	·587	·534	·345	·163	·450	·095	·912
26	·530	·221	·403	·556	·366	·183	·475	·952	·769

	Inclination. γ_2	Node. $\Omega-\Gamma_2$
	°	°
1894 Dec. 27	0·4839	160·26
1895 Jan. 26	·4838	161·23
Feb. 25	·4837	162·21
Mar. 27	·4836	163·18
Apr. 26	·4835	164·16
May 26	0·4834	165·13

Third Satellite.

Greenwich Noon. 1894–95.	Longitude. l_3-L	N_3	Arguments. α_3	β_3	γ_3	δ_3	ϵ_3
	°	°					
July 30	123·6997	−·0097	·7523	·9303	·4955	·210	·739
Aug. 9	266·8758	·0098	·1498	·3279	·9138	·008	·178
19	50·0519	·0099	·5473	·7256	·3320	·807	·617
29	193·2280	·0100	·9448	·1232	·7503	·605	·056
Sept. 8	336·4041	·0101	·3423	·5209	·1685	·404	·495
18	119·5802	·0102	·7398	·9185	·5868	·202	·934
28	262·7563	−·0102	·1373	·3162	·0051	·001	·373
Oct. 8	45·9324	·0103	·5348	·7139	·4233	·799	·812
18	189·1085	·0104	·9323	·1115	·8416	·598	·251
28	332·2846	·0105	·3299	·5092	·2598	·396	·690
Nov. 7	115·4607	·0106	·7274	·9068	·6781	·195	·129
17	258·6369	·0107	·1249	·3045	·0963	·993	·568
27	41·8130	−·0107	·5224	·7021	·5146	·792	·007
Dec. 7	184·9891	·0108	·9199	·0998	·9328	·590	·446
17	328·1652	·0108	·3174	·4975	·3511	·389	·885
27	111·3413	·0109	·7149	·8950	·7693	·187	·324
Jan. 6	254·5174	·0110	·1124	·2928	·1876	·986	·763
16	37·6935	·0110	·5100	·6904	·6058	·784	·202
26	180·8696	−·0111	·9075	·0881	·0241	·583	·641
Feb. 5	324·0457	·0111	·3050	·4857	·4423	·381	·080
15	107·2218	·0112	·7025	·8834	·8606	·180	·519
25	250·3979	·0112	·1000	·2811	·2789	·978	·958
Mar. 7	33·5740	·0113	·4975	·6787	·6971	·777	·397
17	176·7501	·0113	·8950	·0764	·1154	·575	·836
27	319·9262	−·0114	·2925	·4740	·5336	·374	·275
Apr. 6	103·1023	·0114	·6900	·8717	·9519	·173	·714
16	246·2784	·0114	·0876	·2693	·3701	·971	·153
26	29·4545	·0115	·4851	·6670	·7884	·770	·592
May 6	172·6306	·0115	·8826	·0647	·2066	·568	·031
16	315·8067	·0115	·2801	·4623	·6249	·367	·470
26	98·9828	−·0115	·6776	·8600	·0431	·165	·909

	Inclination. γ_3	Node. $\odot-\Gamma_3$		Inclination. γ_3	Node. $\odot-\Gamma_3$
	°	°		°	°
1894 July 30	0·1256	126·57	1894 Dec. 27	0·1254	127·81
Aug. 29	·1255	126·83	1895 Jan. 26	·1254	128·05
Sept. 28	·1255	127·08	Feb. 25	·1254	128·29
Oct. 28	·1254	127·32	Mar. 27	·1254	128·52
Nov. 27	·1254	127·57	Apr. 26	·1254	128·74
Dec. 27	0·1254	127·81	May 26	0·1255	128·96

Third Satellite.

Greenwich Noon. 1894–95.		Arguments. ζ_3	η_3	θ_3	i_3
	30	·903	·243	·065	·592
Aug.	9	·925	·264	·086	·989
	19	·947	·285	·106	·385
	29	·969	·306	·127	·782
Sept.	8	·990	·326	·148	·178
	18	·012	·347	·168	·575
	28	·034	·368	·189	·971
Oct.	8	·056	·388	·209	·368
	18	·077	·409	·230	·764
	28	·099	·430	·251	·161
Nov.	7	·121	·451	·271	·557
	17	·143	·471	·292	·954
	27	·164	·492	·312	·350
Dec.	7	·186	·513	·333	·747
	17	·208	·534	·354	·143
	27	·230	·554	·374	·540
Jan.	6	·251	·575	·395	·936
	16	·273	·596	·415	·333
	26	·295	·617	·436	·729
Feb.	5	·317	·637	·457	·126
	15	·338	·658	·477	·522
	25	·360	·679	·498	·919
Mar.	7	·382	·700	·518	·315
	17	·404	·720	·539	·712
	27	·425	·741	·560	·108
Apr.	6	·447	·762	·580	·505
	16	·469	·783	·601	·901
	26	·491	·803	·621	·298
May	6	·512	·824	·642	·694
	16	·534	·845	·663	·091
	26	·556	·866	·683	·487

Fourth Satellite.

Longitude. l_4-O	S_4	Arg. a_4
° 228·2240	− ° 0320	·22060
83·9347	·0323	·81975
299·6455	·0325	·41889
155·3562	·0327	·01803
11·0669	·0329	·61717
226·7777	·0331	·21631
82·4884	−·0333	·81546
298·1992	·0335	·41460
153·9099	·0336	·01374
9·6206	·0338	·61288
225·3314	·0340	·21202
81·0421	·0341	·61117
296·7529	−·0343	·41031
152·4636	·0344	·00945
8·1743	·0346	·60859
223·8851	·0347	·20773
79·5958	·0348	·80688
295·3066	·0350	·40602
151·0173	−·0351	·00516
6·7280	·0352	·60430
222·4388	·0353	·20344
78·1495	·0354	·80258
293 8603	·0355	·40173
149·5710	·0356	·00087
5·2817	−·0356	·60001
220·9925	·0357	·19915
76·7032	·0357	·79829
292·4140	·0358	·39744
148·1247	·0359	·99658
3·8354	·0359	·59572
219·5462	−·0359	·19486

1894.	Inclination. γ_4	Node. $\Omega-\Gamma_4$
July 30	° 0·3438	° 28·12
Aug. 29	·3433	28·13
Sept. 28	·3428	28·14
Oct. 28	·3424	28·16
Nov. 27	·3419	28·19
Dec. 27	0·3415	28·22

Fourth Satellite.

Greenwich Noon. 1894–95.	Arguments. β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	θ_4
July 30	·210	·543	·390	·610	·489	·705	·167
Aug. 9	·008	·142	·984	·804	·688	·922	·367
19	·807	·741	·579	·998	·888	·139	·566
29	·605	·340	·174	·192	·087	·355	·766
Sept. 8	·404	·939	·768	·386	·287	·572	·965
18	·202	·538	·363	·579	·486	·789	·165
28	·001	·137	·958	·773	·685	·006	·364
Oct. 8	·799	·736	·552	·967	·885	·223	·564
18	·598	·335	·147	·161	·084	·439	·763
28	·396	·934	·742	·354	·283	·656	·963
Nov. 7	·195	·533	·336	·548	·483	·873	·162
17	·993	·132	·931	·742	·682	·090	·362
27	·792	·731	·525	·936	·882	·306	·561
Dec. 7	·590	·330	·120	·130	·081	·523	·761
17	·389	·929	·715	·323	·280	·740	·960
27	·187	·528	·309	·517	·480	·957	·160
Jan. 6	·986	·127	·904	·711	·679	·173	·359
16	·784	·726	·499	·905	·878	·390	·559
26	·583	·325	·093	·098	·078	·607	·758
Feb. 5	·381	·924	·688	·292	·277	·824	·958
15	·180	·523	·283	·486	·477	·041	·157
25	·978	·122	·877	·680	·676	·257	·357
Mar. 7	·777	·721	·472	·874	·875	·474	·556
17	·575	·320	·066	·067	·075	·691	·756
27	·374	·919	·661	·261	·274	·908	·955
Apr. 6	·173	·518	·256	·455	·473	·124	·155
16	·971	·117	·850	·649	·673	·341	·355
26	·770	·716	·445	·842	·872	·558	·554
May 6	·568	·315	·040	·036	·071	·775	·754
16	·367	·914	·634	·230	·271	·991	·953
26	·165	·513	·229	·424	·470	·208	·153

	Inclination. γ_4	Node. $\Omega-\Gamma_4$
	°	°
1894 Dec. 27	0·3415	28·22
1895 Jan. 26	·3410	28·26
Feb. 25	·3406	28·30
Mar. 27	·3402	28·34
Apr. 26	·3399	28·39
May 26	0·3395	28·45

Col. Cooper's Observatory:
Markree, Collooney, Ireland.

Ephemeris for Physical Observations of Jupiter,

Greenwich Noon.	Position-angle of ♃'s Axis. P	L−O	Diff.	B	A−L	Apparent Diameter. Equat.	Defect.	Polar.
1894.	°	°		°	°	″	″	″
Dec. 17	1·808	316·654	270	+2·181	−1·236	46·81	0·01	43·80
19	1·682	316·384	272	2·181	−0·796	46·83	...	43·82
21	1·556	316·112	272	2·180	−0·354	46·84	...	43·83
23	1·429	315·840	272	2·180	+0·088	46·84	...	43·83
25	1·302	315·568	271	2·179	+0·530	46·82	...	43·81
27	1·175	315·297	269	+2·178	+0·970	46·78	...	43·78
29	1·050	315·028	266	2·178	1·409	46·73	·01	43·73
31	0·926	314·762	262	2·177	1·845	46·67	·01	43·67
1895.								
Jan. 2	0·803	314·500	258	2·176	2·277	46·60	·02	43·60
4	0·683	314·242	253	2·174	2·705	46·51	·03	43·52
6	0·565	313·989	246	+2·173	+3·127	46·40	0·03	43·42
8	0·450	313·743	240	2·171	3·543	46·29	·04	43·31
10	0·338	313·503	233	2·170	3·953	46·16	·05	43·20
12	0·229	313·270	225	2·168	4·355	46·02	·07	43·07
14	0·123	313·045	216	2·166	4·749	45·87	·08	42·92
16	0·022	312·829	207	+2·164	+5·135	45·71	0·09	42·77
18	359·925	312·622	198	2·161	5·511	45·54	·11	42·61
20	·833	312·424	187	2·159	5·878	45·35	·12	42·44
22	·746	312·237	177	2·156	6·235	45·16	·13	42·26
24	·663	312·060	165	2·153	6·581	44·96	·15	42·07
26	359·586	311·895	153	+2·150	+6·915	44·75	0·16	41·88
28	·514	311·742	142	2·147	7·238	44·53	·18	41·67
30	·448	311·600	129	2·144	7·548	44·31	·19	41·46
Feb. 1	·388	311·471	117	2·140	7·846	44·08	·21	41·25
3	·333	311·354	104	2·137	8·132	43·84	·22	41·03
5	359·284	311·250	91	+2·133	+8·405	43·60	0·23	40·80
7	·242	311·159	78	2·129	8·665	43·36	·25	40·57
9	·205	311·081	65	2·125	8·912	43·11	·26	40·34
11	·175	311·016	51	2·121	9·145	42·85	·27	40·10
13	·151	310·765	38	2·116	9·366	42·60	·28	39·86
15	359·133	310·927	25	+2·112	+9·573	42·34	0·29	39·62
17	·121	310·902	12	2·107	9·766	42·08	·30	39·38
19	·116	310·890	2	2·103	9·946	41·82	·31	39·13
21	·117	310·892	15	2·098	10·113	41·55	·32	38·88
23	·124	310·907	29	2·093	10·266	41·29	·33	38·64

1894-95. (*Concluded.*) By A. Marth.

Greenwich Noon.	Bright-ness.	Longitude of Ψ's. Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O	B
1894.	m	°	°	°	m	°	°
Dec. 17	−2·28	17·26	38·64	+0·01	34·593	315·4197	+2·1529
19	−2·28	333·34	339·46	·00	34·575	315·5898	2·1464
21	−2·28	289·41	280·28	...	34·569	315·7599	2·1399
23	−2·28	245·48	221·09	...	34·572	315·9299	2·1334
25	−2·28	201·55	161·89	...	34·587	316·0998	2·1268
27	−2·28	157·60	102·68	·00	34·612	316·2697	+2·1202
29	−2·28	113·65	43·47	−0·01	34·647	316·4395	2·1136
31	−2·27	69·69	344·25	·01	34·693	316·6093	2·1070
1895.							
Jan. 2	−2·27	25·71	285·02	·02	34·750	316·7791	2·1004
4	−2·26	341·73	225·78	·03	34·817	316·9488	2·0938
6	−2·26	297·74	166·52	−0·04	34·894	317·1185	+2·0872
8	−2·25	253·73	107·26	·05	34·981	317·2881	2·0805
10	−2·25	209·71	47·98	·07	35·078	317·4576	2·0738
12	−2·24	165·68	348 69	·08	35·184	317·6271	2·0671
14	−2·23	121·63	289·38	·10	35·300	317·7966	2·0604
16	−2·22	77·57	230·06	−0·12	35·425	317·9660	+2·0537
18	−2·21	33·50	170·73	·13	35·560	318·1353	2·0469
20	−2·20	349·41	111·38	·15	35·703	318·3046	2·0401
22	−2·19	305·30	52·01	·17	35·855	318·4739	2·0333
24	−2·18	261·18	352·63	·19	36·015	318·6431	2·0265
26	−2·17	217·04	293·24	−0·21	36·183	318·8123	+2·0197
28	−2·16	172·89	233·82	·23	36·360	318·9814	2·0129
30	−2·15	128·72	174·39	·25	36·544	319·1505	2·0061
Feb. 1	−2·14	84·53	114·95	·27	36·735	319·3195	1·9992
3	−2·13	40·33	55·49	·29	36·932	319·4885	1·9923
5	−2·11	356·11	356·01	−0·31	37·137	319·6574	+1·9854
7	−2·10	311·87	296·51	·33	37·347	319·8263	1·9785
9	−2·09	267·62	237·00	·35	37·563	319·9951	1·9716
11	−2·07	223·35	177·47	·36	37·785	320·1639	1·9647
13	−2·06	179·06	117·92	·38	38·013	320·3326	1·9577
15	−2·05	134·76	58·36	−0·40	38·245	320·5013	+1·9507
17	−2·03	90·44	358·78	·42	38·482	320·6699	1·9437
19	−2·02	46·10	299·19	·43	38·723	320·8385	1·9367
21	−2·00	1·75	239·58	·45	38·969	321·0070	1·9297
23	−1·99	317·38	179·95	·46	39·218	321·1755	1·9227

Greenwich Noon.	Position-angle of ℳ's Axis. P	L−O.	Diff.	B	A−L.	Apparent Diameter. Equat.	Defect.	Polar.
1895.	°	°		°	°	″	″	″
Feb. 25	359·137	310·936	42	+2·088	+10·406	41·02	0·34	38·39
27	·157	310·978	55	2·083	10·532	40·76	·34	38·14
Mar. 1	·183	311·033	68	2·078	10·646	40·50	·35	37·90
3	·215	311·101	81	2·073	10·746	40·24	·35	37·65
5	·253	311·182	93	2·067	10·833	39·98	·36	37·41
7	359·296	311·275	105	+2·061	+10·908	39·72	0·36	37·16
9	·345	311·380	118	2·056	10·971	39·46	·36	36·92
11	·401	311·498	130	2·050	11·021	39·20	·36	36·68
13	·462	311·628	142	2·044	11·059	38·95	·36	36·45
15	·528	311·770	153	2·038	11·085	38·70	·36	36·21
17	359·599	311·923	165	+2·032	+11·100	38·45	0·36	35·98
19	·676	312·088	176	2·026	11·103	38·21	·36	35·75
21	·758	312·264	186	2·019	11·095	37·97	·35	35·53
23	·846	312·450	198	2·013	11·076	37·73	·35	35·31
25	359·939	312·648	208	2·006	11·046	37·50	·35	35·09
27	0·036	312·856	218	+1·999	+11·006	37·27	0·34	34·87
29	0·138	313·074	228	1·992	10·955	37·04	·34	34·66
31	0·245	313·302	238	1·985	10·895	36·82	·33	34·45
Apr. 2	0·356	313·540	247	1·978	10·825	36·60	·33	34·25
4	0·472	313·787	257	1·971	10·745	36·39	·32	34·05
6	0·593	314·044	265	+1·964	+10·656	36·18	0·31	33·85
8	0·717	314·309	274	1·957	10·558	35·97	·30	33·66
10	0·845	314·583	282	1·949	10·451	35·77	·30	33·47
12	0·977	314·865	291	1·941	10·336	35·57	·29	33·29
14	1·113	315·156	298	1·933	10·212	35·38	·28	33·11
16	1·253	315·454	306	+1·925	+10·081	35·19	0·27	32·93
18	1·396	315·760	314	1·917	9·942	35·01	·26	32·76
20	1·543	316·074	321	1·909	9·796	34·83	·25	32·59
22	1·693	316·395	328	1·900	9·642	34·65	·24	32·43
24	1·846	316·723	335	1·891	9·481	34·48	·24	32·27
26	2·002	317·058	341	+1·883	+9·314	34·32	0·23	32·11
28	2·162	317·399	347	1·874	9·139	34·16	·22	31·96
30	2·325	317·746	354	1·865	8·958	34·00	·21	31·81
May 2	2·490	318·100	360	1·855	8·771	33·85	·20	31·67
4	2·658	318·460	365	1·846	8·578	33·70	·19	31·53
6	2·828	318·825	371	+1·836	+8·380	33·55	0·18	31·40
8	3·000	319·196	376	1·827	8·176	33·42	·17	31·27
10	3·175	319·572		1·817	7·966	33·28	·16	31·14

Greenwich Noon.	Brightness.	Longitude of ☿'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A − O.	B
1895.	m	°	°	°	m	°	°
Feb. 25	−1·98	273·00	120·31	−0·47	39·470	321·3439	+1·9157
27	−1·96	228·60	60·65	·48	39·726	321·5123	1·9087
Mar. 1	−1·95	184·19	0·98	·49	39·984	321·6806	1·9016
3	−1·93	139·76	301·30	·50	40·244	321·8489	1·8945
5	−1·92	95·32	241·60	·51	40·507	322·0171	1·8874
7	−1·90	50·87	181·88	−0·52	40·771	322·1853	+1·8803
9	−1·89	6·40	122·16	·52	41·037	322·3534	1·8731
11	−1·87	321·92	62·42	·53	41·304	322·5215	1·8660
13	−1·86	277·43	2·67	·53	41·572	322·6895	1·8588
15	−1·85	232·92	302·90	·53	41·840	322·8575	1·8516
17	−1·83	188·41	243·13	−0·54	42·109	323·0254	+1·8444
19	−1·82	143·88	183·34	·54	42·378	323·1933	1·8372
21	−1·80	99·34	123·54	·54	42·647	323·3611	1·8300
23	−1·79	54·79	63·73	·53	42·915	323·5289	1·8228
25	−1·78	10·23	3·91	·53	43·183	323·6966	1·8156
27	−1·76	325·66	304·09	−0·53	43·450	323·8643	+1·8084
29	−1·75	281·08	244·25	·52	43·716	324·0319	1·8011
31	−1·73	236·49	184·40	·52	43·980	324·1995	1·7938
Apr. 2	−1·72	191·89	124·54	·51	44·242	324·3671	1·7865
4	−1·71	147·28	64·68	·50	44·503	324·5346	1·7792
6	−1·70	102·67	4·81	−0·49	44·761	324·7020	+1·7719
8	−1·68	58·05	304·93	·48	45·017	324·8694	1·7646
10	−1·67	13·42	245·04	·47	45·271	325·0367	1·7573
12	−1·66	328·78	185·14	·46	45·521	325·2040	1·7499
14	−1·65	284·14	125·24	·45	45·769	325·3713	1·7425
16	−1·64	239·49	65·34	−0·44	46·014	325·5385	+1·7351
18	−1·62	194·84	5·43	·43	46·256	325·7056	1·7277
20	−1·61	150·18	305·51	·42	46·494	325·8727	1·7203
22	−1·60	105·52	245·59	·41	46·729	326·0398	1·7129
24	−1·59	60·85	185·66	·39	46·960	326·2068	1·7055
26	−1·58	16·18	125·73	−0·38	47·187	326·3737	+1·6980
28	−1·57	331·50	65·79	·36	47·410	326·5406	1·6906
30	−1·56	286·82	5·85	·35	47·629	326·7075	1·6831
May 2	−1·55	242·13	305·91	·34	47·843	326·8743	1·6756
4	−1·54	197·44	245·96	·32	48·052	327·0411	1·6681
6	−1·53	152·75	186·01	−0·31	48·257	327·2078	+1·6606
8	−1·52	108·06	126·06	·29	48·458	327·3744	1·6531
10	−1·51	63·37	66·10	·28	48·653	327·5410	1·6456

The following is a list (continued from p. 569) of Greenwich mean times when the zero-meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc:

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1894.	h m	h m	1895.	h m	h m
Dec. 17	9 22·1	8 51·6	Jan. 3	4 49·2	7 50·9
	19 12·5	18 47·2		14 39·6	17 46·5
18	5 2·9	4 42·8	4	10 20·4	3 42·1
	14 53·3	14 38·4		20 10·9	13 37·7
19	10 34·1	10 29·5	At 23^h·4 δ of $\mathcal{U}$ with * 4^m.1		
	20 24·5	20 25·1	1 Geminorum.		
20	6 15·0	6 20·7	5	6 1·3	9 28·9
	16 5·4	16 16·3		15 51·7	19 24·6
21	1 55·8	2 11·9	6	1 42·2	5 20·2
	11 46·2	12 7·5		11 32·6	15 15·8
22	7 27·0	7 58·6	7	7 13·5	1 11·4
	17 17·4	17 54·2		17 3·9	11 7·0
23	3 7·8	3 49·8	8	2 54·4	6 58·2
	12 58·2	13 45·4		12 44·8	16 53·9
24	8 39·0	9 36·6	9	8 25·7	2 49·5
	18 29·4	19 32·2		18 16·2	12 45·1
25	4 19·9	5 27·8	10	4 6·6	8 36·3
	14 10·3	15 23·3		13 57·1	18 32·0
26	9 51·1	1 18·9	11	9 38·0	4 27·6
	19 41·5	11 14·5		19 28·4	14 23·2
27	5 31·9	7 5·7	12	5 18·9	0 18·8
	15 22·4	17 1·3		15 9·3	10 14·5
28	1 12·8	2 56·9	13	0 59·8	6 5·7
	11 3·2	12 52·5		10 50·2	16 1·4
29	6 44·0	8 43·7	14	6 31·1	1 57·0
	16 34·5	18 39·3		16 21·6	11 52·6
30	2 24·9	4 34·9	15	2 12·0	7 43·9
	12 15·3	14 30·5		12 2·5	17 39·5
31	7 56·2	10 21·7	16	7 43·4	3 35·2
	17 46·6	20 17·3		17 33·9	13 30·8
1895.					
Jan. 1	3 37·0	6 12·9	17	3 24·3	9 22·1
	13 27·4	16 8·5		13 14·8	19 17·7
2	9 8·3	2 4·1	18	8 55·7	5 13·4
	18 58·7	11 59·7		18 46·2	15 9·0

	I. (877°·90)		II. (870°·27)			I. (877°·90)		II. (870°·27)	
1895.	h	m	h	m	1895.	h	m	h	m
Jan. 19	4	36·7	1	4·7	Feb. 6	15	29·0	15	49·9
	14	27·1	11	0·3	7	1	19·5	1	45·6
20	0	17·6	6	51·6		11	10·0	11	41·3
	10	8·1	16	47·3	8	6	51·0	7	32·7
21	5	49·0	2	42·9		16	41·6	17	28·4
	15	39·5	12	38·6	9	2	32·1	3	24·1
22	1	30·0	8	29·9		12	22·6	13	19·8
	11	20·5	18	25·5	10	8	3·7	9	11·2
23	7	1·4	4	21·2		17	54·2	19	6·9
	16	51·9	14	16·8	11	3	44·7	5	2·7
24	2	42·4	0	12·5		13	35·3	14	58·4
	12	32·9	10	8·2	12	9	16·4	0	54·1
25	8	13·8	5	59·5		19	6·9	10	49·8
	18	4·3	15	55·1	13	4	57·4	6	41·2
26	3	54·8	1	50·8		14	48·0	16	36·9
	13	45·3	11	46·5	14	0	38·5	2	32·7
27	9	26·3	7	37·8		10	29·1	12	28·4
	19	16·8	17	33·5	15	6	10·1	8	19·8
28	5	7·3	3	29·2		16	0·7	18	15·5
	14	57·8	13	24·8	16	1	51·2	4	11·3
29	0	48·3	9	16·2		11	41·8	14	7·0
	10	38·8	19	11·8	17	7	22·9	9	58·4
30	6	19·8	5	7·5		17	13·4	19	54·2
	16	10·3	15	3·2	18	3	4·0	5	49·9
31	2	0·8	0	58·9		12	54·5	15	45·6
	11	51·3	10	54·6	19	8	35·6	1	41·4
Feb. 1	7	32·3	6	45·9		18	26·2	11	37·1
	17	22·8	16	41·6	20	4	16·7	7	28·5
2	3	13·3	2	37·3		14	7·3	17	24·3
	12	3·8	12	33·0	21	9	48·4	3	20·0
3	8	44·8	8	24·4		19	39·0	13	15·8
	18	35·3	18	20·0	22	5	29·5	9	7·2
4	4	25·8	4	15·7		15	20·1	19	3·0
	14	16·4	14	11·4	23	1	10·7	4	58·7
5	0	6·9	0	7·1		11	1·2	14	54·5
	9	57·4	10	2·8	24	6	42·4	0	50·2
6	5	38·4	5	54·2		16	32·9	10	45·9

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1895	h m	h m	1895.	h m	h m
Feb. 25	2 23·5	6 37·4	Mar. 15	3 29·4	1 35·4
	12 14·1	16 33·2		13 20·0	11 31·1
26	7 55·2	2 28·9	16	9 1·2	7 22·7
	17 45·8	12 24·7	17	4 42·4	3 14·3
27	3 36·3	8 16·2		14 33·0	13 10·1
	13 26·9	18 11·9	18	10 14·2	9 1·7
28	9 8·1	4 7·7	19	5 55·4	4 53·3
	18 58·6	14 3·4		15 46·1	14 49·0
Mar. 1	4 49·2	9 54·9	20	1 36·7	0 44·8
	14 39·8	19 50·7		11 27·3	10 40·6
2	0 30·4	5 46·5	21	7 8·5	6 32·2
	10 21·0	15 42·2	22	2 49·7	2 23·6
3	6 2·1	1 38·0		12 40·4	12 19·6
	15 52·7	11 33·7	23	8 21·6	8 11·2
4	1 43·3	7 25·3	24	4 2·8	4 2·8
	11 33·9	17 21·0		13 53·5	13 58·6
5	7 15·0	3 16·8	25	9 34·7	9 50·2
	17 5·6	13 12·5	26	5 15·9	5 41·8
6	2 56·2	9 4·1		15 6·6	15 37·6
	12 46·8	18 59·8	27	0 57·2	1 33·4
7	8 28·0	4 55·6		10 47·8	11 29·2
	18 18·6	14 51·4	28	6 29·1	7 20·8
8	4 9·2	0 47·2	29	2 10·3	3 12·4
	13 59·8	10 42·9		12 1·0	13 8·2
9	9 40·9	6 34·5	30	7 42·2	8 59·9
	19 31·5	16 30·2	31	3 23·5	4 51·5
10	5 22·1	2 26·0		13 14·1	14 47·3
	15 12·7	12 21·8	Apr. 1	8 55·4	10 38·9
11	1 3·3	8 13·3	2	4 36·6	6 30·5
	10 53·9	18 9·1	3	0 17·9	2 22·2
12	6 35·1	4 4·9		10 8·5	12 18·0
	16 25·7	14 0·7	4	5 49·8	8 9·6
13	2 16·3	9 52·2	5	1 31·1	4 1·2
	12 6·9	19 48·0		11 21·7	13 57·0
14	7 48·1	5 43·8	6	7 3·0	9 48·7
	17 38·7	15 39·6	7	2 44·3	5 40·3

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1895.	h m	h m	1895.	h m	h m
Apr. 7	12 34·9	15 36·1	Apr. 20	5 44·9	11 26·7
8	8 16·2	11 27·8	21	1 26·2	7 18·4
9	3 57·5	7 19·4	22	6 58·2	13 5·9
10	9 29·4	13 6·9	23	2 39·5	8 57·5
11	5 10·7	8 58·5	24	8 11·4	4 49·2
12	0 52·0	4 50·1	25	3 52·7	10 36·7
	10 42·6	14 46·0	26	9 24·7	6 28·4
13	6 23 9	10 37·6	27	5 6·0	12 15·9
14	2 5·2	6 29·3	28	10 38·0	8 7·5
15	7 37·1	12 16·8	30	11 51·3	9 46·7
16	3 18·4	8 8·4	May 1	7 32·6	5 38·4
17	8 50·4	13 55·9	2	13 4·6	11 25·9
18	4 31·7	9 47·5	3	8 45·9	7 17·6
19	10 3·6	5 39·2	5	9 59·2	8 56·8

The intervals between successive passages of the zero-meridian vary in System I. between $9^h\ 50^m{\cdot}40$ and $50^m{\cdot}66$, and in II. between $9^h\ 55^m{\cdot}58$ and $55^m{\cdot}84$. The differences of successive values of the longitudes of ♃'s Central Meridian for the intervals of two days vary in System I. between 1755°·31 and 1756°·10, and in II. between 1740°·04 and 1740°·84.

The jovicentric latitudes B of the Earth above the plane of *Jupiter's* equator on pp. 562 and 564 are by mistake 0°·004 too small, or the values there given require a correction of +0°·004.

The formulæ for computing the apparent positions of markings on the planet's spheroidal surface are given on p. 159. If y is the distance of a belt from the centre of the disc measured along the polar semi-axis b of the disc, the latitude β' of the belt is found by means of

$$\sin(\beta' - B') = \frac{y}{b}$$

where the values of B′ are

1894 July	30	+2°·59	1894 Nov.	7	+2°·34	1895 Feb.	15	+2°·26
Aug.	19	2·52		27	2·33	Mar.	7	2·20
Sept.	8	2·45	Dec.	17	2·33		27	2·14
	28	2·39	1895 Jan.	6	2·32	Apr.	16	2·06
Oct.	18	+2·35		26	+2·30	May	6	+1·96

Though the conjunction of *Jupiter* with the star 1 *Geminorum* $4^m{\cdot}3$ on January 4 is not a very close one, the passage of the planet's system within 1′ of a bright star is rare enough to

render the occurrence one of some interest and worth watching. Assuming the apparent place of the star to be—

$$\alpha\ 5^h\ 57^m\ 45^s\cdot 81 \quad \delta + 23^\circ\ 16'\ 15''\cdot 7$$

the planet and its four satellites in their retrograde course will pass the star in right-ascension in the following order :—

	h	m	
1895 Jan. 4	11	5 Gr.	Sat. III. 56″·6 south of *
	17	14	Sat. I. 48″·2 „ „
	22	9	Preceding limb
	23	23	Centre of 4 44″·8 south of *, so that the north rim of the disc passes at a distance of 23″.
5	0	37	Following limb
	9	5	Sat. II. 49″·9 south of *
6	1	53	Sat. IV. 52″·2 „ „

Further details may be gathered from the following apparent differences of right-ascension and declination between the satellites and the centre of *Jupiter*, which are founded upon the data in the next paper and the tables in vol. li. :—

Sat. III.

1895.	G.M.T. h	m	$\alpha_3 - A.$ s	$\delta_3 - D.$ ″
Jan. 4	8	0	−14·693	−9·25
	9		15·450	8·83
	10		16·185	8·41
	11		16·898	7·97
	12		17·589	7·53
	13		18·255	7·07
	14	0	−18·896	−6·60

Sat. II.

1895.	G.M.T. h	m	$\alpha_2 - A.$ s	$\delta_2 - D.$ ″
Jan. 5	6	0	+14·936	−6·39
	7		14·490	6·99
	8		13·963	7·55
	9		13·359	8·07
	10		12·682	8·54
	11		11·936	8·97
	12	0	+11·124	−9·34

Sat. I.

			$\alpha_1 - A.$ s	$\delta_1 - D.$ ″
	16	0	− 7·323	−2·44
		20	7·651	2·18
		40	7·960	1·92
	17	0	8·250	1·67
		20	8·519	1·42
		40	8·767	1·16
	18	0	8·994	0·89
		20	9·199	0·62
		40	− 9·380	−0·35

Sat. IV.

			$\alpha_4 - A.$ s	$\delta_4 - D.$ ″
	6	0	+36·982	−14·68
		1	36·570	14·92
		2	36·152	15·16
		3	35·726	15·39
		4	35·290	15·62
		5	34·843	15·85
		6 0	+34·385	−16·08

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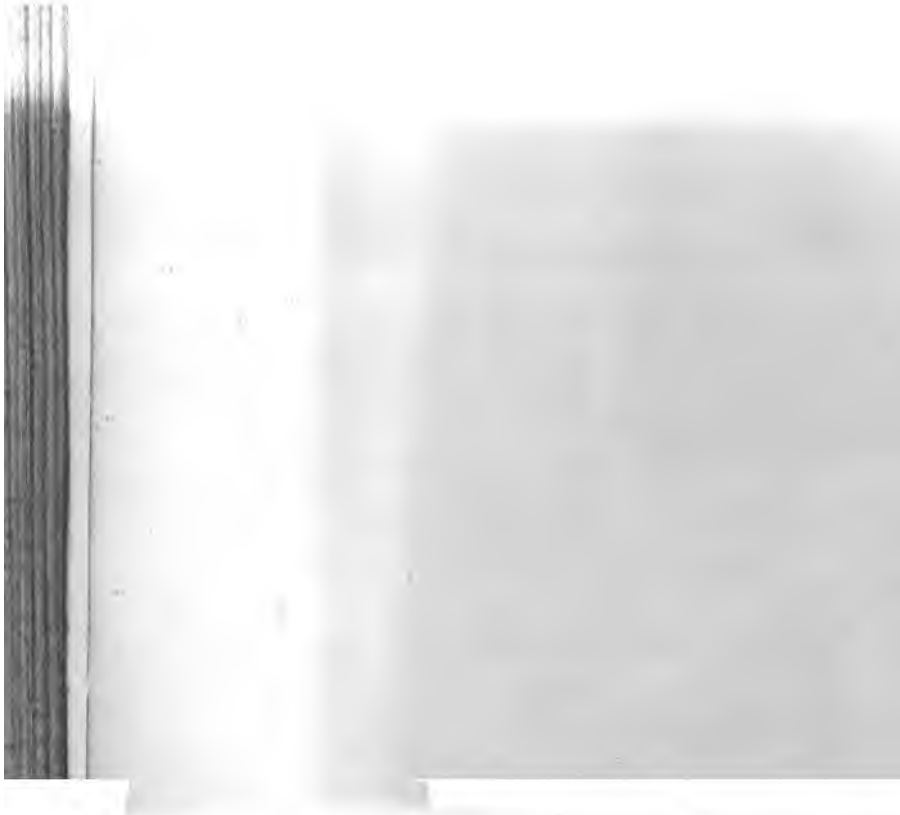

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